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Comprehensive Reclamation and Engineering Plan
Sand Coulee Drainage - Cascade County, Montana

PHASE I REPORT
Reclamation Alternatives

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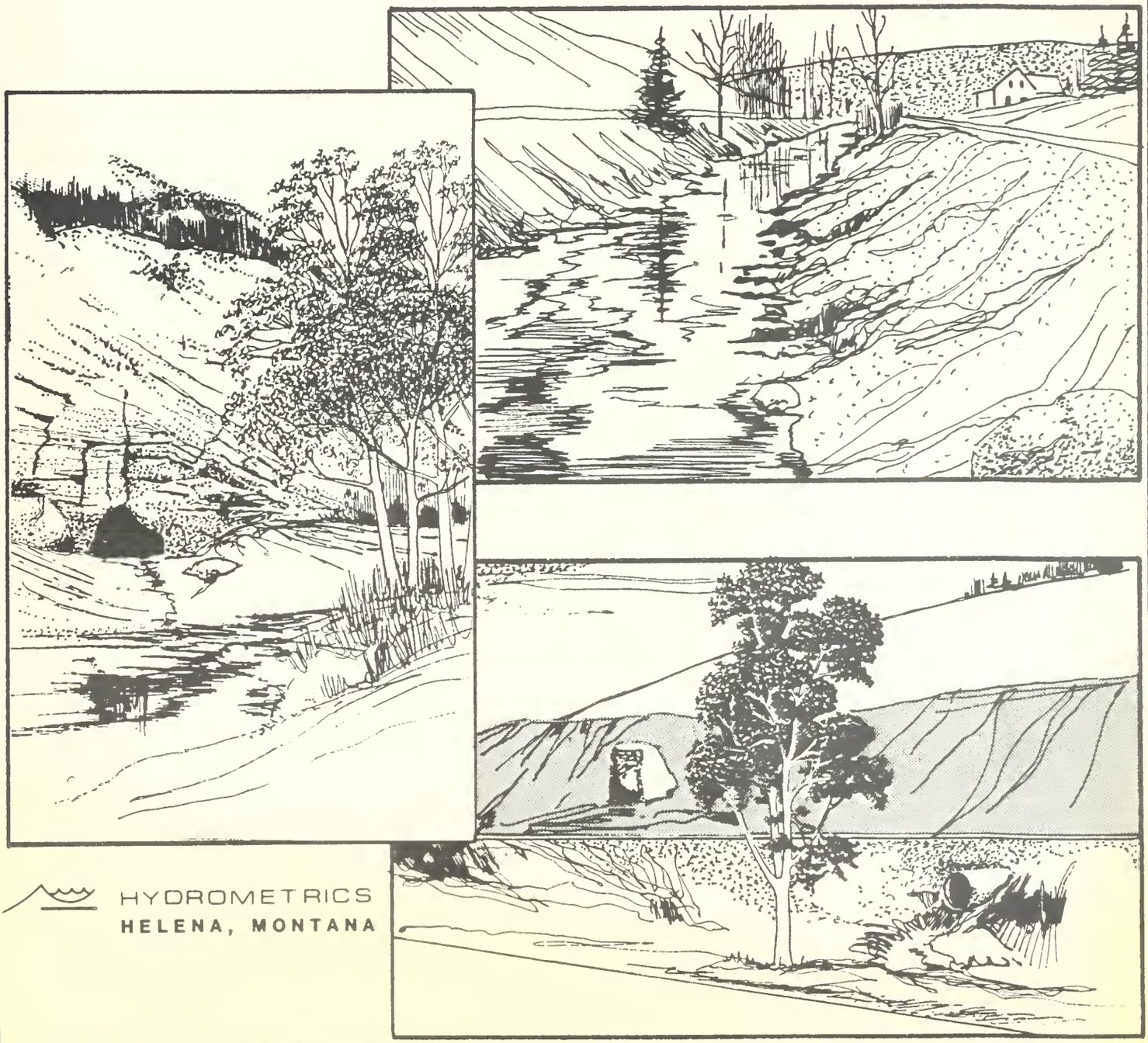

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COMPREHENSIVE RECLAMATION AND ENGINEERING PLAN
SAND COULEE DRAINAGE - CASCADE COUNTY, MONTANA

PHASE I REPORT
RECLAMATION ALTERNATIVES

for

Richard L. Juntunen, Chief
Abandoned Mine Bureau
Department of State Lands
1625 Eleventh Avenue
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July 15, 1983

Mr. Dick Juntunen
Chief - Abandoned Mine Department
Department of State Lands
1625 Eleventh Avenue
Helena, Montana 59620

Dear Dick,

Enclosed are three copies of our Phase I report of the Comprehensive Reclamation and Engineering Plan - Sand Coulee Drainage - Cascade County, Montana.

We look forward to discussing these reclamation options with you and your staff and proceeding with Phase II of the project.

Please call me if you have any questions on this report or if you need additional information for your alternative selections.

Sincerely,

M. K. Botz, P.E.
Hydrologist/Engineer

MKB:jy

Enclosures

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SUMMARY

A detailed inventory and evaluation of Sand Coulee study area AML-related disturbances has been completed. A total of 30 mine waste dumps, approximately 40 subsidence depressions, 6 acid mine discharges, 10 open adits, 22 collapsed adits, two open air shafts and several AML-related water resource problems have been identified. Reclamation options for all identified AML-related disturbances have been evaluated and specific reclamation or mitigation procedures recommended for each site. Major recommended reclamation projects include:

1) Plugging open adits and air shafts which constitute a safety hazard;
2) Controlling erosion and flooding that impacts private property;
3) Stream channel alterations including culvert replacement and selective riprap and revegetation to reduce flooding and erosion;
4) Reclamation of mine waste dumps by both onsite and offsite disposal methods to reduce erosion, acid runoff and visual impacts;
5) Reclamation of subsidence depressions to reduce inflow to underground mine workings,
6) Continued study of one potentially contaminated well.

Total cost of recommended reclamation alternatives is estimated to range from about $272,000 to $412,000.

COMPREHENSIVE RECLAMATION AND ENGINEERING PLAN
SAND COULEE DRAINAGE - CASCADE COUNTY, MONTANA

PHASE I REPORT
RECLAMATION ALTERNATIVES

Abandoned coal mine disturbances in the vicinity of Sand Coulee, Montana degrade land and water resources and affect a number of private landowners. The Montana Department of State Lands (DSL) has undertaken a detailed evaluation of the mining-related disturbances and has begun to fund site specific reclamation projects under the Abandoned Mine Land (AML) program. As part of this program, Hydrometrics was contracted by DSL to conduct a detailed study of a portion of the Sand Coulee drainage. This work is in accordance with the January 1983 DSL Request for Proposal and the February 1983 proposal to DSL from Hydrometrics and Robert Peccia and Associates. The purpose of this Phase I report is to provide DSL with the information necessary to select appropriate reclamation alternatives for abandoned mine lands in the Sand Coulee study area.

This Phase I report expands on the Sand Coulee-Belt Master Plan (Hydrometrics - Westech, 1982) by focusing on a specific study area in the vicinity of the community of Sand Coulee and providing a range of site specific reclamation alternatives for AML disturbances in the study area. Following DSL's determination of appropriate reclamation measures for the AML disturbances in the study area, detailed engineering plans and specifications will be prepared as Phase II of this project.

SCOPE

The scope of work for this project is outlined in the Hydrometrics Comprehensive Reclamation and Engineering Plan - Final Proposal (January 1983). Major tasks include:

1) Review of existing AML-related information;
2) Description of the existing hydrologic system;
3) Inventory of AML disturbances;
4) Evaluation of the Sand Coulee stream channel system, and
5) Development of reclamation alternatives for the stream channel, waste dumps and other AML-related disturbances.

Phase I is intended to provide information on a wide range of possible reclamation alternatives including risks, benefits and relative costs. Emphasis has been placed on providing cost-effective solutions where risks to health, safety and damage to personal property are involved.

Acid mine drainage (AMD) has significantly affected Sand Coulee throughout most of the study area. Surface water runoff from tributary coulees causes occasional local flooding and sedimentation problems for a number of residents of the town of Sand Coulee. Restricted channel capacities and undersized culverts in the main channel apparently has contributed to minor flooding in the communities of Sand Coulee and Tracy. Continuous and seasonal inflows of acid groundwater to several basements are also of concern to local residents. Problems from abandoned mine lands in the study area were identified by detailed field examinations and interviews with local residents.

Reclamation alternates are described for both general and site specific solutions to AML-related problems in the Sand Coulee-Tracy study area.

Study area location and boundaries are shown on Figure 1. Abbreviations used in this report are defined when first used and are listed in Appendix A. Geographic features described in this report are located using the U. S. Bureau of Land Management tract delineation system (Appendix B).

PREVIOUS WORK

Previous work in the Sand Coulee-Tracy area includes several studies of the effects of abandoned mine disturbances and acid mine drainage on the hydrologic system. McArthur (1970) conducted an investigation of acid mine drainage in the Stockett-Sand Coulee area including a detailed inventory of springs and AMD. He monitored pH and flows of mine discharges and obtained some water quality data for acid discharges in the area. The Soil Conservation Service (1973) evaluated and reported on channel capacities and flooding problems in the Sand Coulee drainage. Hydrometrics-Westech (1982) prepared a comprehensive report on mining-related disturbances in the Belt-Sand Coulee area which included an inventory of mine dumps and acid mine drainages; collection of some hydrologic data and assessment of reclamation measures. The Montana Bureau of Mines and Geology (1983) conducted a study of surface water and groundwater systems influenced by acid mine drainage in the Stockett-Sand Coulee area. The Montana Bureau of Mines

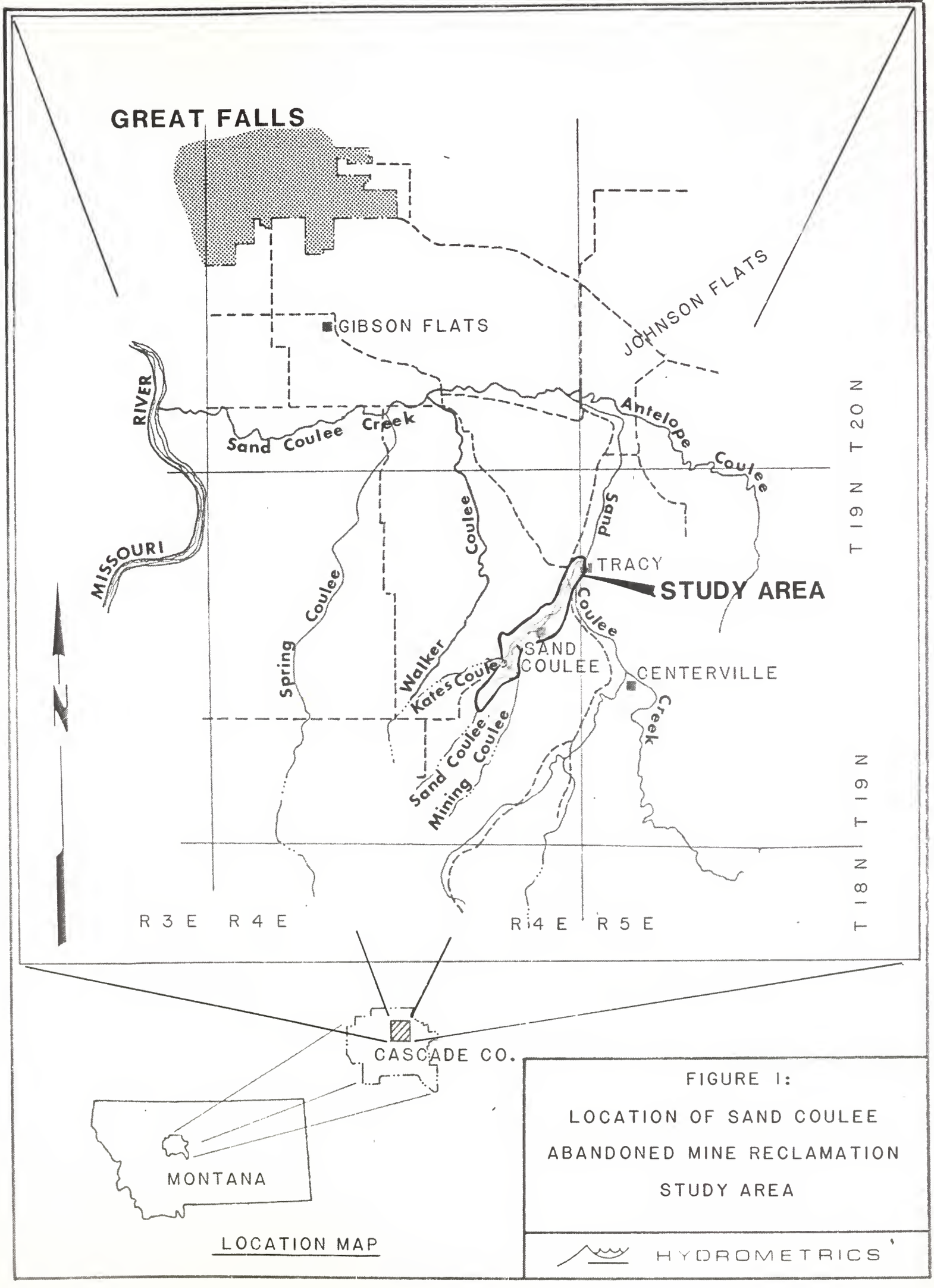


FIGURE 1:
LOCATION OF SAND COULEE
ABANDONED MINE RECLAMATION
STUDY AREA

HYDROMETRICS

and Geology (MBMG) report contains data on surface water flows, water quality and an updated well and spring inventory.

These previous reports present baseline information and problem definition used in this evaluation of AML disturbances and reclamation alternatives. Considerable information has also been obtained from DSL staff who have been involved with Sand Coulee area AML investigations and reclamation activities for several years.

HYDROLOGIC SYSTEM ANALYSIS

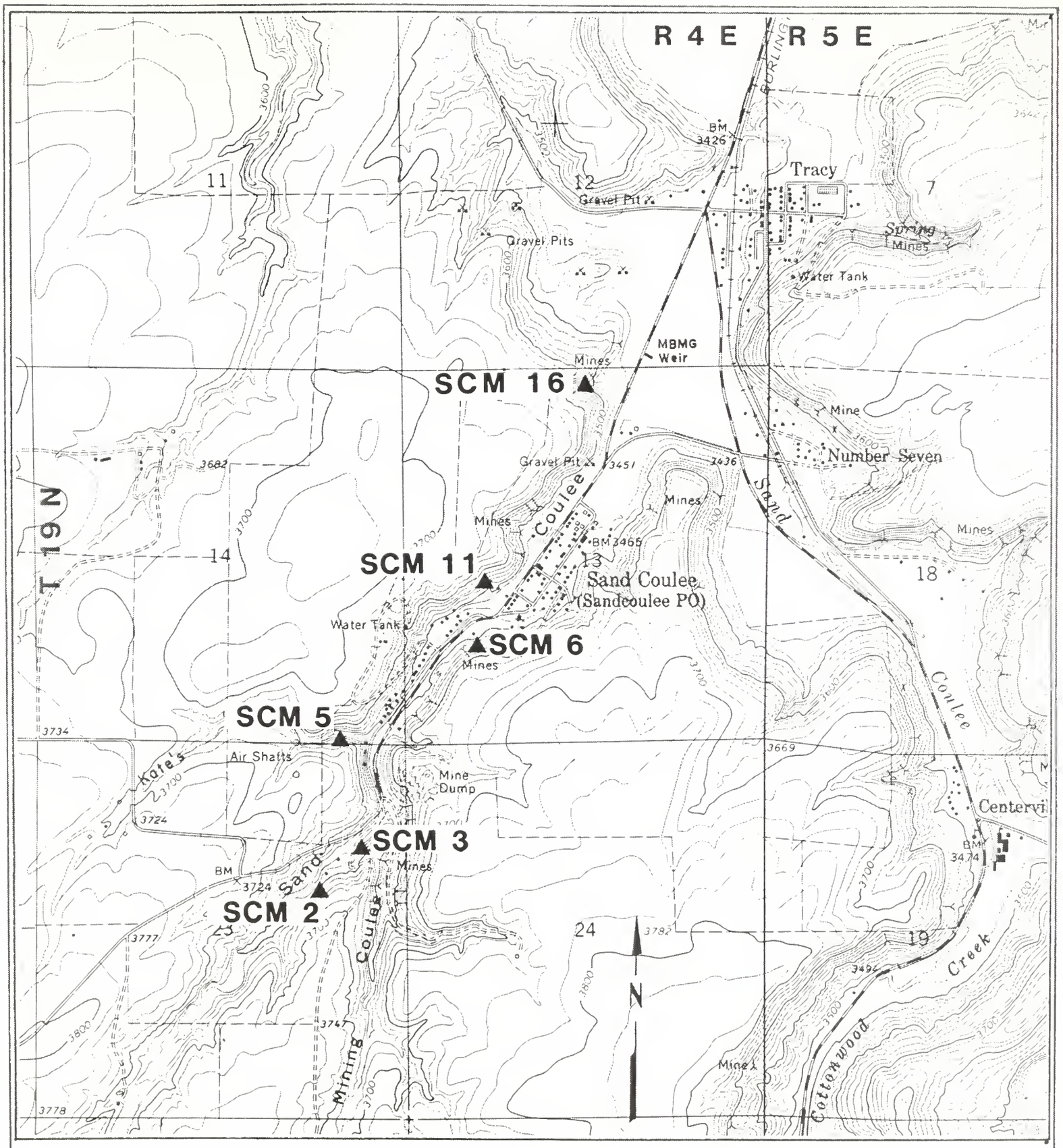
SAND COULEE DRAINAGE

Sand Coulee (also referred to as Rusty Ditch, Sand Coulee Fork, No Name Creek or Straight Creek) originates about 3.5 miles southwest of the town of Sand Coulee and flows northeast to its confluence with Sand Coulee Creek just north of Tracy (Figure 1). Sand Coulee has a drainage area of about seven square miles at its confluence with Sand Coulee Creek near Tracy.

Sand Coulee is intermittent above the abandoned mines and receives flow in this upper reach from a few small springs. Surface runoff occurs only in response to spring snowmelt or intense rainfall. Sand Coulee receives water from discharging abandoned mines and continuously flows for a considerable distance downstream of the discharge from mine SCM 2 (Figure 2). There are five abandoned coal mines that have continuous or nearly continuous discharges into Sand Coulee; these are SCM 2, SCM 3, SCM 5, SCM 6, and SCM 11 (Figure 2). Additional flows are contributed by a spring in Kate's Coulee and a small flow of AMD from Mining Coulee (Hydrometrics, 1982).

Flow Regime

Flow records for Sand Coulee include several measurements made by McArthur (1970) over a period of several months in 1969; measurements by Hydrometrics (1982) and by MBMG (1983). The MBMG data includes a



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SCM 2 ▲ ACID MINE DRAINAGE DISCHARGE LOCATION AND DESIGNATION

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FIGURE 2:

LOCATION OF ACID MINE DISCHARGE, SAND COULEE STUDY AREA

HYDROMETRICS Helena, Mt.

continuous flow record from a weir installed downstream of the town of Sand Coulee for the period November 1980 to August 1982.

As part of this study, streamflow measurements were made at ten sites on Sand Coulee upstream of Tracy in March 1983. These sequential flow measurements (termed a seepage run) showed gains and losses in streamflow on that date.

Sand Coulee receives most of its base flow from acid mine discharges. One non-acid spring also contributes flow to Kate's Coulee which is a tributary of Sand Coulee. Downstream of the town of Sand Coulee in the straight section along Highway 227, the stream loses water to the underlying alluvium and was dry above Tracy during the March 1983 seepage run. Flow measurements for the March seepage run were obtained at several cross sections using standard stream gaging techniques and a pygmy type current meter. At other sites, a portable V-throat flume was used to measure flow. Streamflow results for March 26, 1983 are in Table 1.

Existing data shows Sand Coulee to have a large base flow for its drainage area compared to the nearby and much larger Sand Coulee Creek drainage. This base flow is supported primarily by acid mine discharges. The flow in Sand Coulee is seasonally variable. The maximum flow recorded in two years of record by MBMG (1983) was 26 cubic feet per second (cfs). Flow data show frequent winter no-flow

TABLE 1. FLOW DATA FOR SAND COULEE AND ACID MINE DISCHARGES, SPRING 1983

Seepage Run: 3/26/83

Site	Flow (gpm)
Sand Coulee at Culverts 8A and 8B	0
Sand Coulee at Culverts 6A and 6B	0
Sand Coulee at MBMG Wier	84
Sand Coulee 1800 feet above Culvert 5	70
Sand Coulee at Culvert 3	121
Kate's Coulee 250 feet above SCM-5	29
Mining Coulee at Confluence with Sand Coulee	4 Est.
Sand Coulee 10 feet above SCM-2	2 Est.
Sand Coulee 300 feet above SCM-2	0
Sand Coulee 900 feet above SCM-2	10

ACID MINE DISCHARGE (FLOW IN GPM)

	SCM-2	SCM-3	SCM-5	SCM-6	SCM-11	SCM-16
3/26/83	100	13.3	13.6	15.0	2.0	
4/25/83	80	10.5	11.4	12.4	1.4	
5/16/83	75	11.2	17.1	19.7	1.0	
7/1/83						1.5

NOTE: Culvert locations shown on Figure 13, AMD locations shown on Figure 2.

periods and typical summer flows of only a few gallons per minute (gpm) at the MBMG gaging site.

Runoff Analysis

Runoff from the Sand Coulee study area has been estimated using several standard techniques. The SCS (1977) method requires input of soils, vegetation and land use information to develop a curve number and also includes several drainage basin geometric parameters. The USGS (Johnson-Omang, 1976; Parrett and Omang, 1981) methods are regression equation techniques based on regional stream flow records. Runoff values have been calculated for the six sub-drainages in the Sand Coulee study area shown on Figure 3. Runoff at several culverts that do not coincide with the sub-drainage boundaries have also been calculated. Calculated peak runoff values for the 2, 5, 10, 25, 50 and 100 year storm events are in Table 2.

The calculated runoff values show a significant variation between techniques. The SCS (1977) method predicts the highest estimated peak flow and is similar to data developed using the synthetic hydrograph technique (SCS, 1973). The Parrett-Omang (1981) technique is based on regional data and is a revision of an earlier USGS method. This method is relatively accurate on a regional basis. The unique characteristics of the Sand Coulee drainage including the high base flow from AMD and the number of subsidence pits and other openings to underground mine workings may affect the hydrologic response of the drainage. Although the SCS (1977) technique provides greater flow

TABLE 2. PEAK RUNOFF VALUES - SAND COULEE DRAINAGE

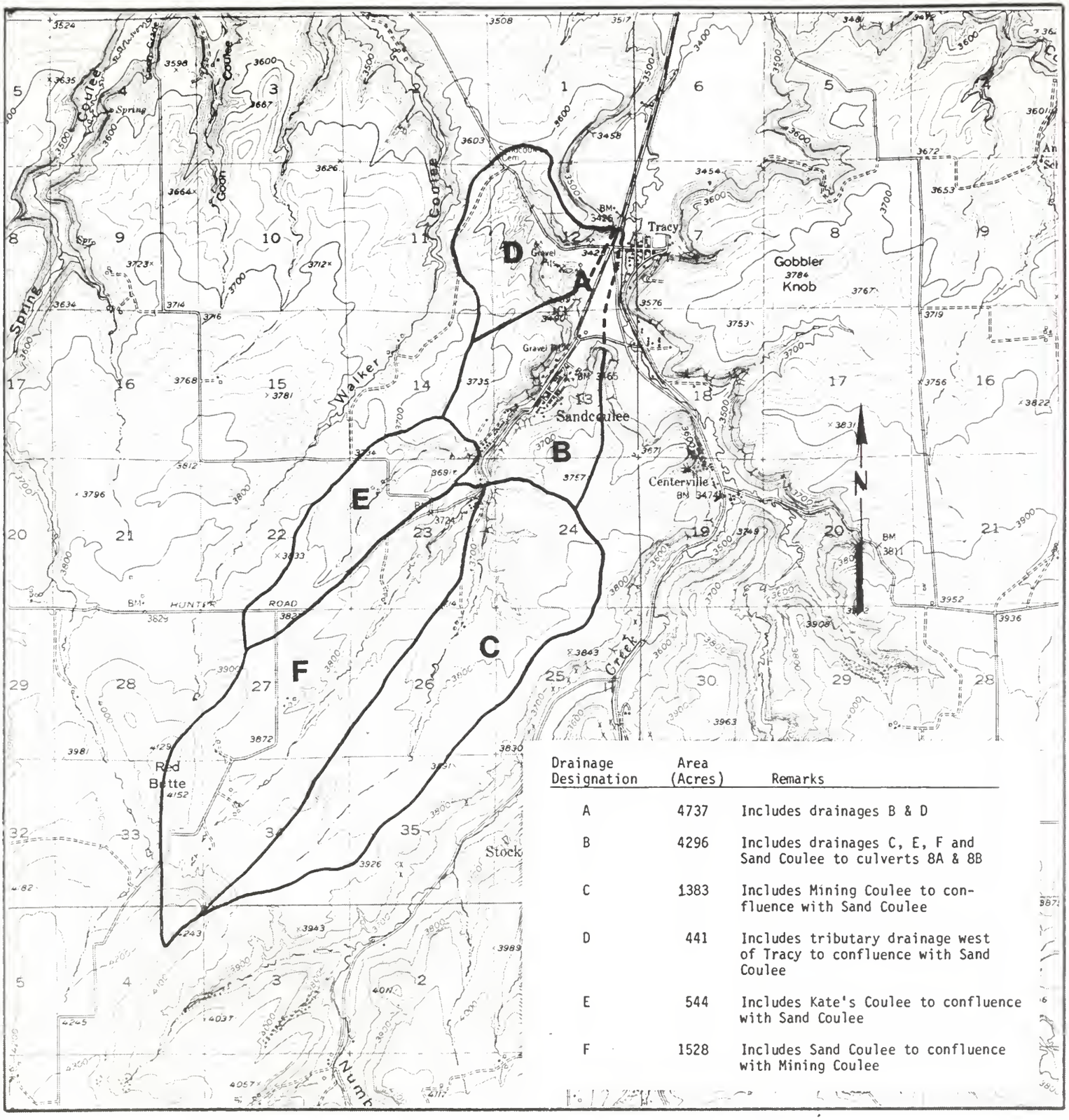
	Site	Method	Discharge (CFS) for Given Recurrence Interval					
			Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
DRAINAGE AREAS	A	SCS	76	217	353	596	781	924
		J-O	23	68	113	189	263	352
		P-O	24	75	140	267	413	617
	B	SCS	69	197	320	539	709	838
		J-O	21	63	106	178	248	332
		P-O	23	71	132	253	391	585
	C	SCS	58	141	209	321	404	467
		J-O	11	35	60	103	146	199
		P-O	9	29	56	110	174	266
	D	SCS	9	33	58	102	136	162
		J-O	5	19	33	58	84	116
		P-O	3	9	17	26	59	93
	E	SCS	16	46	73	120	154	181
		J-O	7	23	40	71	103	142
		P-O	4	12	24	49	79	124
	F	SCS	48	131	200	320	408	477
		J-O	9	29	49	84	118	160
		P-O	10	32	61	120	189	288
CULVERTS	1	SCS	48	131	200	320	408	477
		J-O	9	29	49	84	118	160
		P-O	10	31	59	115	182	278
	2	SCS	74	205	317	514	658	773
		J-O	14	40	67	113	157	210
		P-O	17	53	99	192	299	450
	3	SCS	90	246	381	615	788	924
		J-O	19	57	97	162	227	305
		P-O	20	62	115	221	344	516
	4	SCS	16	46	73	120	154	181
		J-O	7	23	40	71	103	142
		P-O	4	12	24	49	79	123
	5	SCS	64	185	303	513	676	802
		J-O	18	54	90	150	208	278
		P-O	21	65	120	231	359	539
*	6	SCS	69	197	320	539	709	838
	7	J-O	21	63	106	178	248	332
		P-O	23	71	132	253	391	585
	8	SCS	76	217	353	596	781	924
		J-O	23	68	113	189	263	352
		P-O	24	75	140	267	413	617

NOTE: 1) Drainage A and Culvert 8, Drainage B and Culverts 6 & 7, Drainage F and Culvert 1, Drainage E and Culvert 4 are Equivalent Drainage Areas.

2) Locations of Drainage Basins and Culverts are shown on Figures 3 and 13, respectively.

3) SCS = Soil Conservation Service, 1977
J-O = Johnson-Omang, 1976
P-O = Parrett-Omang, 1981

* Runoff values in this row are the same for either Culvert 6 or Culvert 7.



Drainage Designation	Area (Acres)	Remarks
A	4737	Includes drainages B & D
B	4296	Includes drainages C, E, F and Sand Coulee to culverts 8A & 8B
C	1383	Includes Mining Coulee to confluence with Sand Coulee
D	441	Includes tributary drainage west of Tracy to confluence with Sand Coulee
E	544	Includes Kate's Coulee to confluence with Sand Coulee
F	1528	Includes Sand Coulee to confluence with Mining Coulee

LEGEND

(A) DRAINAGE BOUNDARY AND LETTER DESIGNATION SEE TABLE ABOVE

SOURCE OF BASE: U.S.G.S., 1:62500, STOCKETT, MONT.

FIGURE 3:

SUB-DRAINAGE BOUNDARY UTILIZED FOR CALCULATION OF RUNOFF, SAND COULEE

HYDROMETRICS Helena, Mt.

rates, the Parrett-Omang values should be adequate for Sand Coulee channel and culvert design. Should more conservative design flood flow values be desired, the SCS (1977) methodology could be used.

Acid Mine Drainages

Six acid mine drainages contribute flow to Sand Coulee (Figure 2). Five of these AMD's are within the study area; the sixth is in Mining Coulee. There is one additional AMD that does not contribute flow to Sand Coulee. This AMD is designated as SCM 16 and was observed to be flowing in June 1983. Table 3 is a cross reference to the numbering designation systems used to denote these sites in previous reports.

TABLE 3. ACID MINE DRAINAGE INVENTORY DESIGNATION CROSS REFERENCE

Site Number	Location	MBMG (1983)	Hydrometrics-Westech (1982)	McArthur (1970)	DSL
SCM 2	19N04E23ADCB	AS-01	SCM 2	23-6	7-49
SCM 3	19N04E23ADAB	AS-02A AS-02B	SCM 3	23-5	7-49
SCM 5	19N04E14DDCD	AS-04	SCM 5	14-1	7-48
SCM 6	19N04E13CBD	AS-07	SCM 6	13-3	7-48
SCM 11	19N04E13CBA	AS-06	SCM 11	13-6	7-32
SCM 16	19N04E13ABBB	NOT PREVIOUSLY INVENTORIED			

Mine discharges in the study area show considerable variation in discharge rate. Measurements of discharge at SCM 2 have ranged from

less than 50 gpm to about 600 gpm. SCM 5 and SCM 11 had no discharge in April 1982 and have maximum recorded discharges of 75 and 38 gpm, respectively (Hydrometrics, 1982). Mine drainage in the vicinity of Sand Coulee show rapid response to precipitation events which suggests rapid recharge from the land surface downward to mine workings. Average annual acid mine discharge to Sand Coulee is estimated to be about 300 gpm (MBMG, 1983). Flows of five AMD's in the study area were monitored as part of this study during the spring of 1983. Flows were measured with bucket and stopwatch or with a small portable V-section cutthroat flume. Measured discharge rates are in Table 1.

The discharge from SCM 6 has ranged from 1.8 to 250 gpm (Hydrometrics, 1982). Flow at SCM 11 is the smallest in the study area with flows of only a few gallons per minute. Discharges from SCM 6 and SCM 11 have caused flooding or sedimentation damage to private property before reaching Sand Coulee. Discharge from SCM 5 is also reported to have caused flooding in the Kate's Coulee channel but no specific damage has been reported.

Discharge from SCM 2 is located on the east side of Sand Coulee about one mile southeast of the town of Sand Coulee at 19N04E23ADCB. The mine is part of the old Carbon Mine once operated by the Cottonwood Mining Company and Ernest Chartier is the present landowner. The mine portal is no longer visible due to the collapse of the sandstone above the coal. Water flows from the collapsed portal into a ditch and joins Sand Coulee approximately 50 feet from the old portal. Sand Coulee

upstream from SCM 2 is a natural stream fed by snowmelt and rainfall runoff. The stream channel below its confluence with SCM 2 is coated with iron and aluminum precipitates.

SCM 3 is located along the east side of Sand Coulee about 1200 feet downstream from SCM 2 and less than one mile southeast of the town of Sand Coulee at 19N04E23ADAB. SCM 3 also was part of the Carbon Mine operation. Ernest Chartier is owner of the land. The mine portal has completely collapsed and is filled by rock and soil from the overlying roof materials. The area adjacent to the old mine is covered with dark colored shale and slack coal waste material. Discharge from SCM 3 occurs from two locations; from a four-inch PVC and a small wood stave pipe and flows a short distance over the slack pile into Sand Coulee.

SCM 5 is located about 700 to 800 feet up Kate's Coulee near the southwest edge of the community of Sand Coulee at 19N04E14DDCD. SCM 5 was part of the Brown Mine and present ownership is uncertain. The mine portal is still partially open and extends back into the hillside for over 100 feet. A three foot deep pool of mine water extends from 15 feet outside the entrance back into the open adit. The pond overflow discharges through a short section of PVC pipe into Kate's Coulee which passes within 30 feet of the portal. Kate's Coulee is fed by a spring upstream from the mine. The spring water is slightly alkaline and of good quality. The stream below SCM 5 becomes turbid and milky-colored from formation of a precipitate as the alkaline and acid waters

mix. Both aluminum and iron precipitates are abundant on the Kate's Coulee channel bottom.

SCM 6 is located less than one quarter of a mile southwest of the town of Sand Coulee at 19N04E13CBD. This mine is one of several mines located along the hillside and were once operated by the Nelson Mining Company. Ernest Chartier is the present landowner. The discharging adit is located above a large pile of discarded coal and mine wastes which extend an estimated 1500 feet along the hillside south of Sand Coulee. Periodic flow occurs from an adjacent collapsed adit following wet periods (Hydrometrics, 1982; M. Surmi, pers. comm., 1983). Flow was observed occurring from this site in June 1983 but not during earlier 1983 field reconnaissance. The discharge is diverted into a culvert under the road and then it discharges to Sand Coulee. This discharge has historically eroded several steep channelways in the waste pile and has been discharged through several small culverts under the road.

SCM 11 is located on the westside of the town of Sand Coulee at 19N0413CBA. The mine entrance is excavated into sandstone overlying the coal. The portal is timbered and open. The adit is reported to be open for approximately 100 feet into the hillside (Hydrometrics, 1982). Discharge from the mine emerges from the mine wastes over 100 feet away from the portal. This discharge flows down the face of a mine waste pile then through a section of pipe beneath a private road and then is discharged into Sand Coulee.

SCM 16 is located adjacent to waste pile 27 and on June 23, 1983, a small discharge was observed from two sources. The total flow for these two sources was estimated to be about 2 or 3 gpm. On July 1, 1983, only one of the sites was flowing at about 1.5 gpm. The pH of this water was 2.6 and the specific conductivity was about 3500 umhos/cm. This small AMD apparently seeps back into the ground within a few hundred feet of the discharge and has not established any significant channel. The exact source of SCM 16 is difficult to determine but appears to emanating from a collapsed adit through the slack pile. Floors of the two open adits at this site (A9 and A10, Figure 19) are dry.

Water Quality

Water quality of AMD and surface waters of Sand Coulee and Sand Coulee Creek has been the focus of much of the previous hydrologic work in the Stockett and Sand Coulee area. McArthur (1970), Hydrometrics (1982) and MBMG (1983) have collected water quality data and characterized the various acid mine discharges. The AMDs in the study area are iron-aluminum-sulfate type water with low pH (generally 2.5 to 4.0) high electrical conductivity and high concentrations of metals, particularly zinc and nickel. Site SMC 2 and, to a lesser extent, the other four AMDs contribute a significant proportion of the total pollutant load in the Sand Coulee drainage (Hydrometrics, 1982).

Some water quality testing was conducted in conjunction with the 1983 seepage run. Results of these analyses are in Table 4. Water quality

in Sand Coulee is similar to the quality of the major acid mine discharges. Little water quality data exists for Sand Coulee during high flows. Although some dilution and neutralization occurs, some mine drainage has poorer water quality during high flows presumably as a result of flushing of stagnant water and introduction of oxygenated water in mine workings.

TABLE 4. WATER QUALITY ANALYSIS FOR SAND COULEE STUDY AREA

Site	Date Sampled	Total Suspended Solids, mg/l	Specific Conductance @ 25° C, umhos/cm	pH
Sand Coulee above SCM 2	3-26-83	8	807	7.9
SCM 2	3-26-83	4	4,400	2.6
Sand Coulee across from Post Office	3-26-83	75	4,000	2.5
Sand Coulee at Culvert # 3	3-26-83	106	3,960	2.6
Kate's Coulee above SCM-5	3-26-83	17	823	8.1
SCM 5	3-26-83	19	3,270	3.0
SCM 3	3-26-83	4	6,380	2.4
SCM 6	3-26-83	26	5,210	2.6
SCM-11	3-26-83	5	2,030	2.8
Sand Coulee at MBMG Weir	3-26-83	31	4,020	2.6
Mining Coulee above Reclamation	4-8-83	1	6,240	2.3
Mining Coulee MBMG Site AS-03	4-8-83	6	5,810	2.5
SCM 16	7-1-83	3	3,500	2.6

Flooding and Drainage Problems

A study of flood hazards for the entire Sand Coulee Creek drainage was done in 1973 by the Soil Conservation Service. In this study, the 100-year floodway was mapped showing potential areas of fooding. Major floods in the watershed occurred in 1894, 1899, 1908, 1927, 1936, 1953, 1958, 1964, 1965, 1966 and 1969 (SCS, 1973). In addition to these floods, local residents report that a flood occurred in 1954 which was the last time that Sand Coulee exceeded the capacity of culverts at the junction of the Sand Coulee and Centerville roads near Tracy.

Reported flooding within the town of Sand Coulee is the result of a drainage system insufficient to handle high flows. The drainage system of ditches and diversions in the town is in poor condition and often is not able to conduct the runoff through town. This causes flooding in yards and basements in addition to erosion of gravel driveways and streets. During runoff events coal waste material is carried onto private and public property by the water. Local residents report that coal wastes have been deposited on streets near the post office by runoff from the hills southeast of town. Mrs. Richard Wiel reported that her daughter got sick from playing in the runoff water from the same area.

Kate's Coulee is a tributary to Sand Coulee which carries AMD from SCM 5. Below SCM 5, the channel is wide, flat and is coated with iron and aluminum precipitates. It was reported that the runoff from a spring snow storm in May 1983 caused flow out of the banks near the mouth of

the coulee (M. Brown, pers. comm., 1983). The channel overflow directed runoff and AMD onto private property and over the road.

Flooding problems in the Sand Coulee area have often been the result of inadequate channels and culverts and there are several reports of problems associated with the culverts. The most typical problem is that of trash or debris plugging a culvert. Mrs. Gordon Mindt lives near the northeast edge of the study area adjacent to culverts 8A and 8B under the railroad tracks below Tracy. She reported that a bedspring once became trapped in front of the culverts and caused flooding of their house and yard. Culvert 8B was partially filled with sediment in April 1983. Culverts 1 and 5 were also partially obstructed with sediment and debris in April 1983. It was reported that during periods of flooding the stream splits at culvert 3 and part of the flow is directed down the streets for about 1200 feet until it reenters the main channel (P. Parker, pers. comm., 1983).

Mrs. Bill Tesinsky reported problems with ice and erosion on their road each winter from the freezing of the small pipe which passes AMD from SCM 11. Mrs. Mary Surmi has had problems with AMD drainage flooding her basement and yard. This problem was apparently worst during 1982 and is temporarily controlled by a diversion ditch installed by DSL in spring 1983.

Results of interviews with local residents indicating AML-related problems are summarized in Appendix C.

STREAM CHANNEL EVALUATION

CHANNEL DESCRIPTION

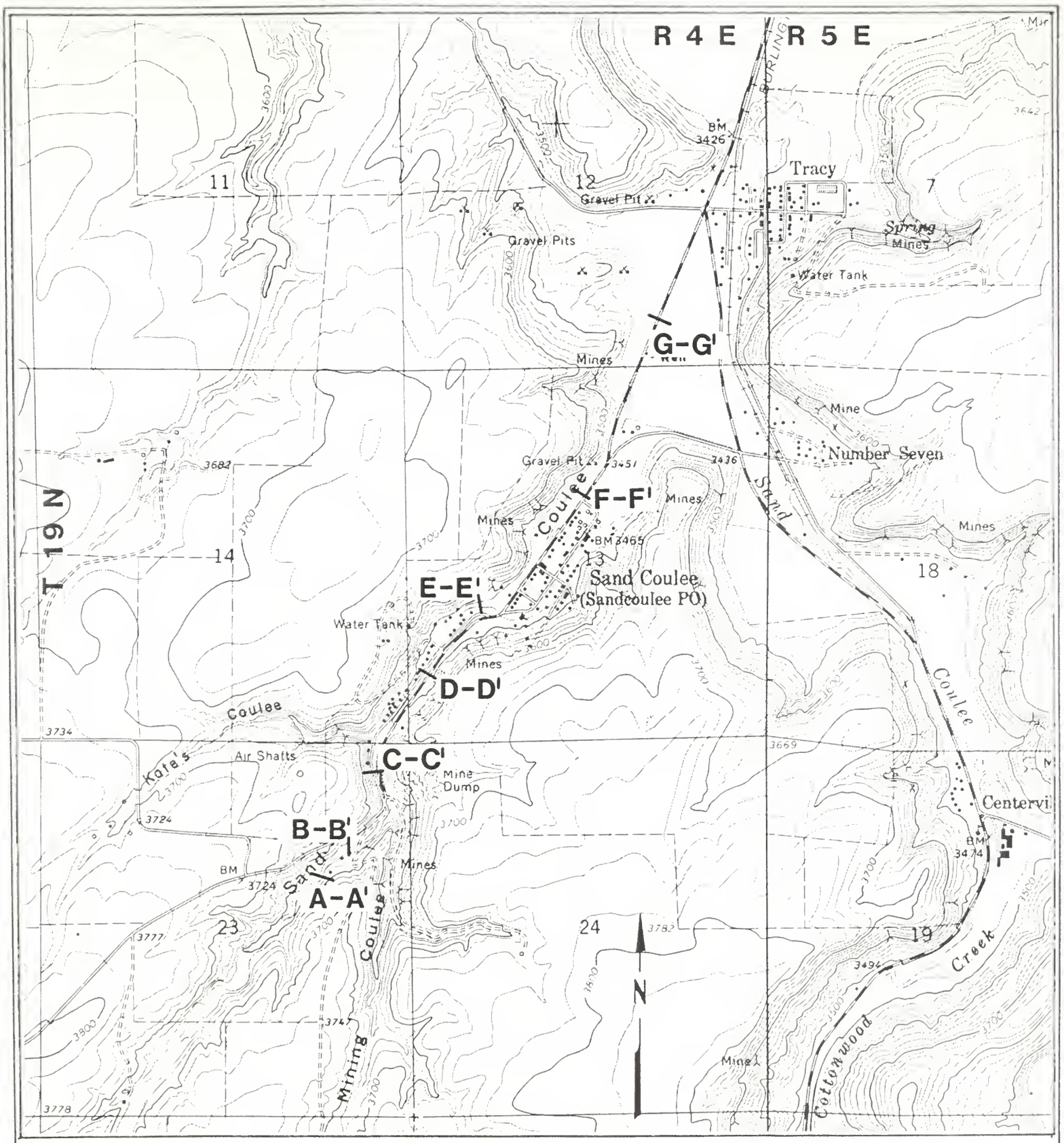
The Sand Coulee stream channel has been extensively impacted by mining disturbance and AMD. Coal mine wastes including slack coal, overburden and clinker provides a significant sediment source to the drainage. Precipitates of iron and aluminum compounds coat much of the channel bottom and are a major factor in channel aggradation. Past channel straightening, inadequately sized culverts and trash and debris accumulation also affect flows in the Sand Coulee channel. The character of the channel, affected by acid mine water through the communities of Sand Coulee and Tracy, is significantly different than either upstream or downstream of the study area. The broad shallow channel in the study area is unsightly and susceptible to flooding and erosion.

The Sand Coulee channel can be divided into geomorphically distinct reaches based on stream channel sinuosity. The stream above its confluence with Mining Coulee is largely undisturbed and is affected by AMD only for a relatively short distance above the confluence. This channel reach is relatively steep with little meandering and meets Schumm's (1963) definition of a transitional channel. From the confluence of Mining Coulee to the junction of Sand Coulee and Sand Coulee Creek, the channel would be classified as "straight" under Schumm's five catagory classification. Sand Coulee Creek below Tracy meanders through the central portion of the valley and is classified as

irregular. These differences are also illustrated by the sinuosity index method of Mueller (1968). Calculated hydraulic sinuosity index values range from 0.14 above Mining Coulee to 0.07 from the Mining Coulee confluence to Tracy and 0.87 for Sand Coulee Creek below Tracy. The evaluation of sinuosity allows a semi-quantitative comparison of stream reaches and establishes a baseline for consideration of reclamation alternatives.

As part of this study of the Sand Coulee drainage, Hydrometrics conducted a survey of the stream channel in May 1983. The survey consisted of a longitudinal channel profile and several channel cross sections (Figures 4 through 12). Channel cross section locations are shown on Figure 4 and on Exhibit 1. The survey was tied into USGS benchmark TCB-8, elevation 3426.03 located at 19N04E12ADAC. Stations along the longitudinal profile are either at the channel centerline at cross sections or the upstream invert at culvert crossings.

The longitudinal profile (Figure 5) shows several oversteepened sections that may reflect response of the stream to channel shortening and may, in part, result from local channel elevation control by culverts. A smooth concave longitudinal profile is generally more stable in unconsolidated sediments than one with frequent changes in gradient or nick points. The lowest gradient sections downstream of culvert 5 below the town of Sand Coulee is a reach of sediment deposition and channel aggradation. The long, straight, low gradient channel between Sand Coulee and Tracy is also a losing stream where



LEGEND

A-A' \ CROSS SECTION LOCATION AND DESIGNATION

SOURCE OF BASE: U.S.G.S., 1:24000, SOUTHEAST GREAT FALLS, MONT.

FIGURE 4:

LOCATION OF CHANNEL CROSS SECTIONS, SAND COULEE DRAINAGE

HYDROMETRICS Helena, Mt.

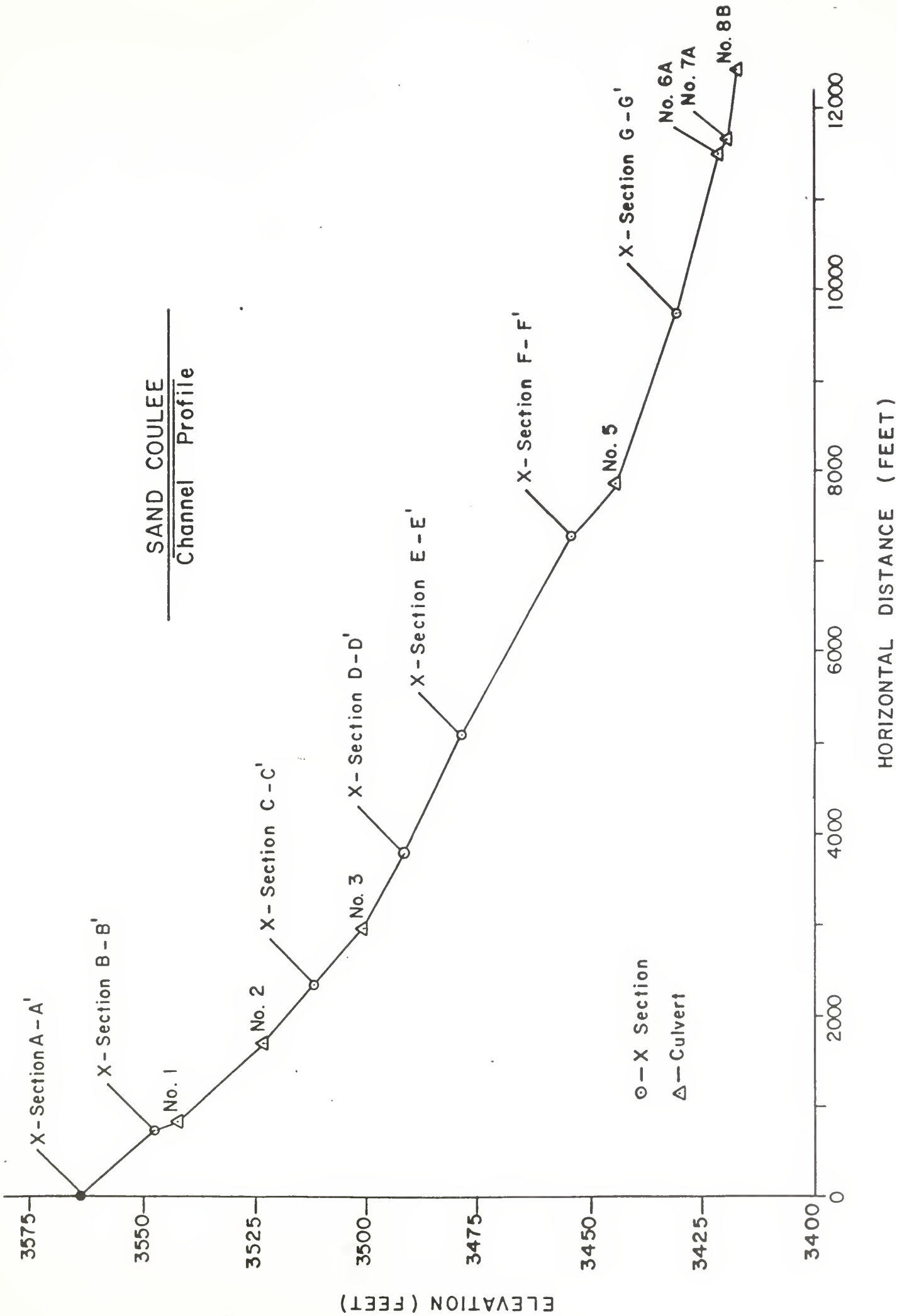


FIGURE 5: SAND COULEE CHANNEL LONGITUDINAL PROFILE

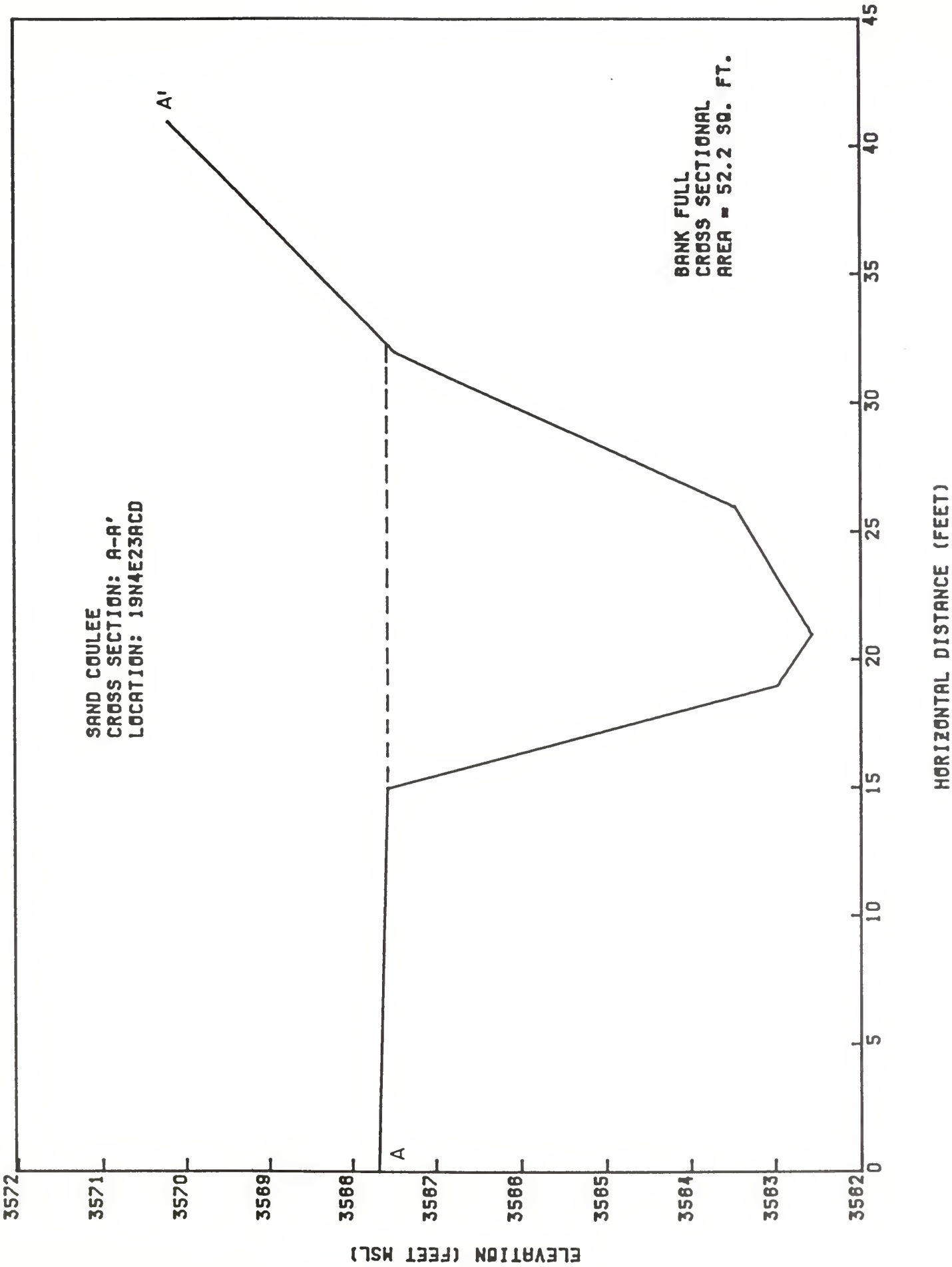


FIGURE 6: SAND COULEE CROSS SECTION A-A'

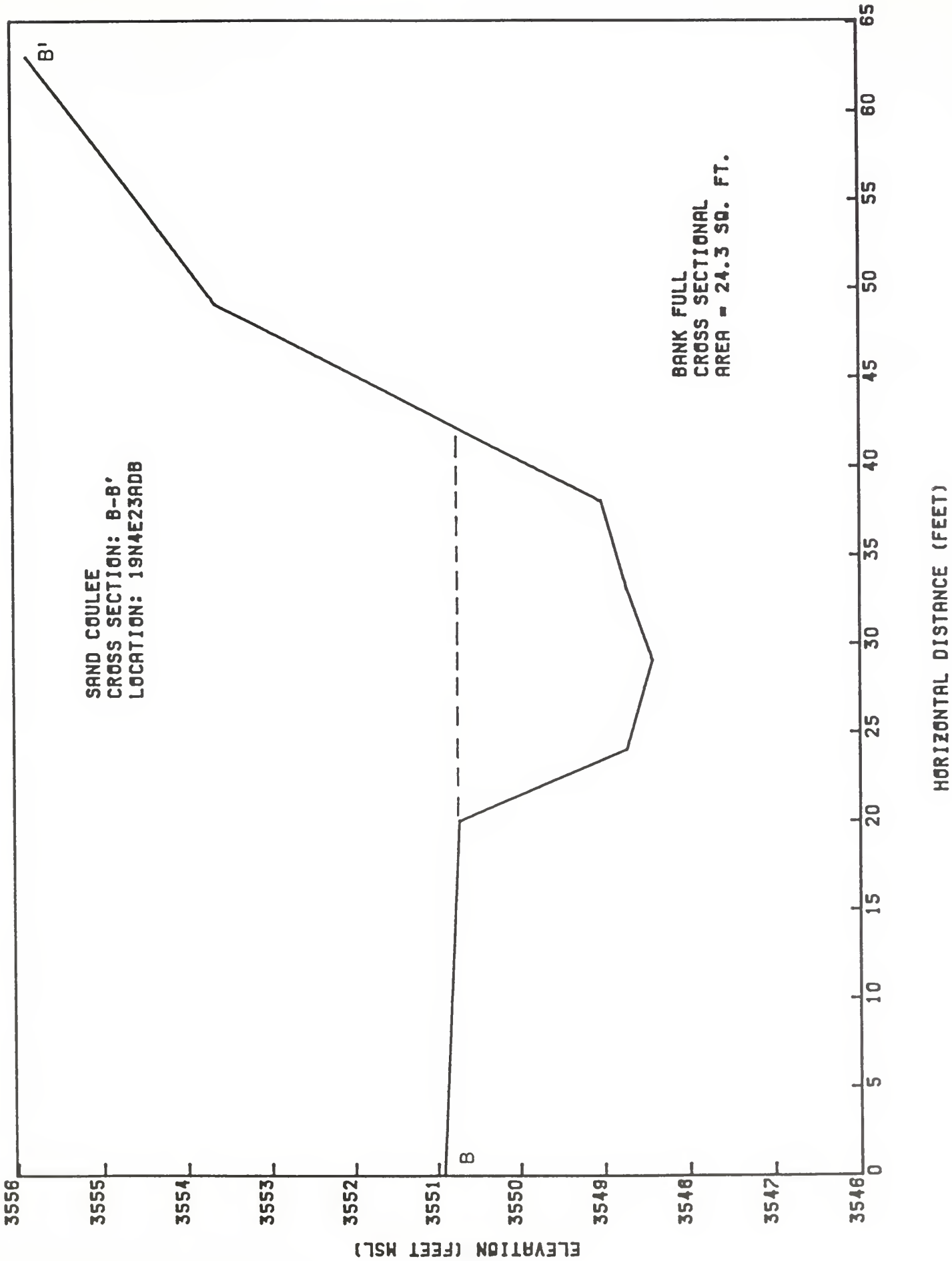


FIGURE 7: SAND COULEE CROSS SECTION B-B'

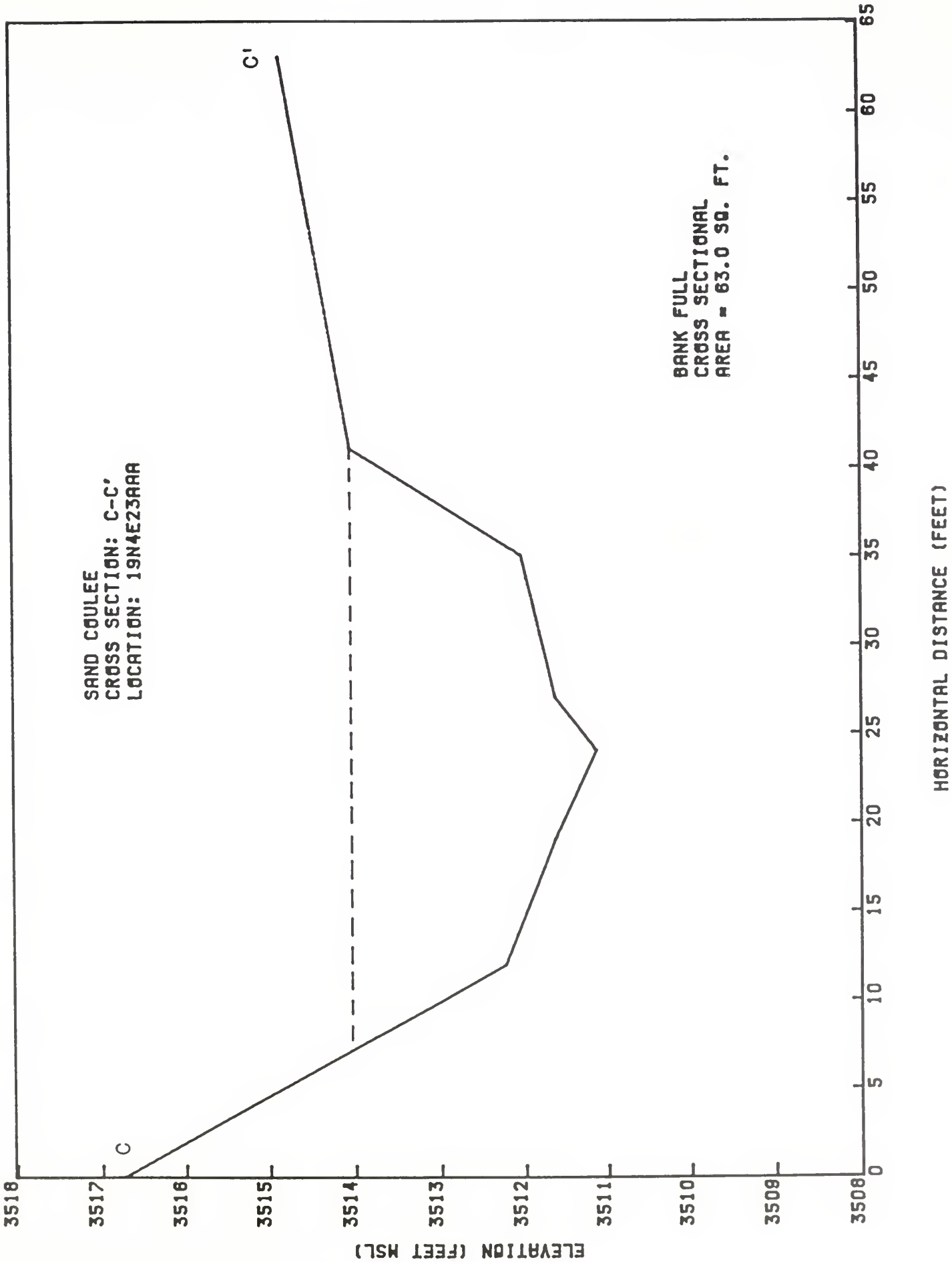


FIGURE 8: SAND COULEE CROSS SECTION C-C'

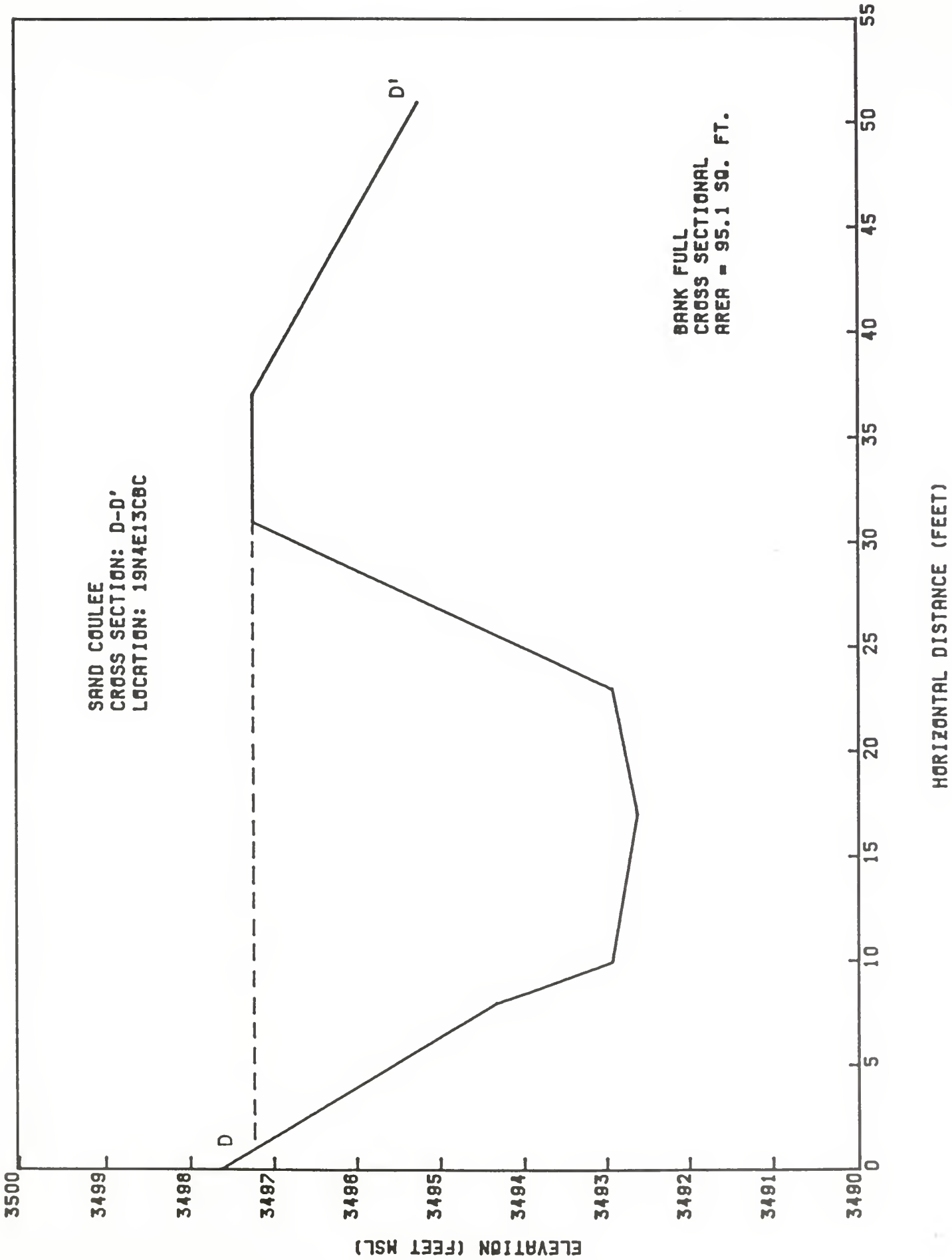


FIGURE 9: SAND COULEE CROSS SECTION D-D'

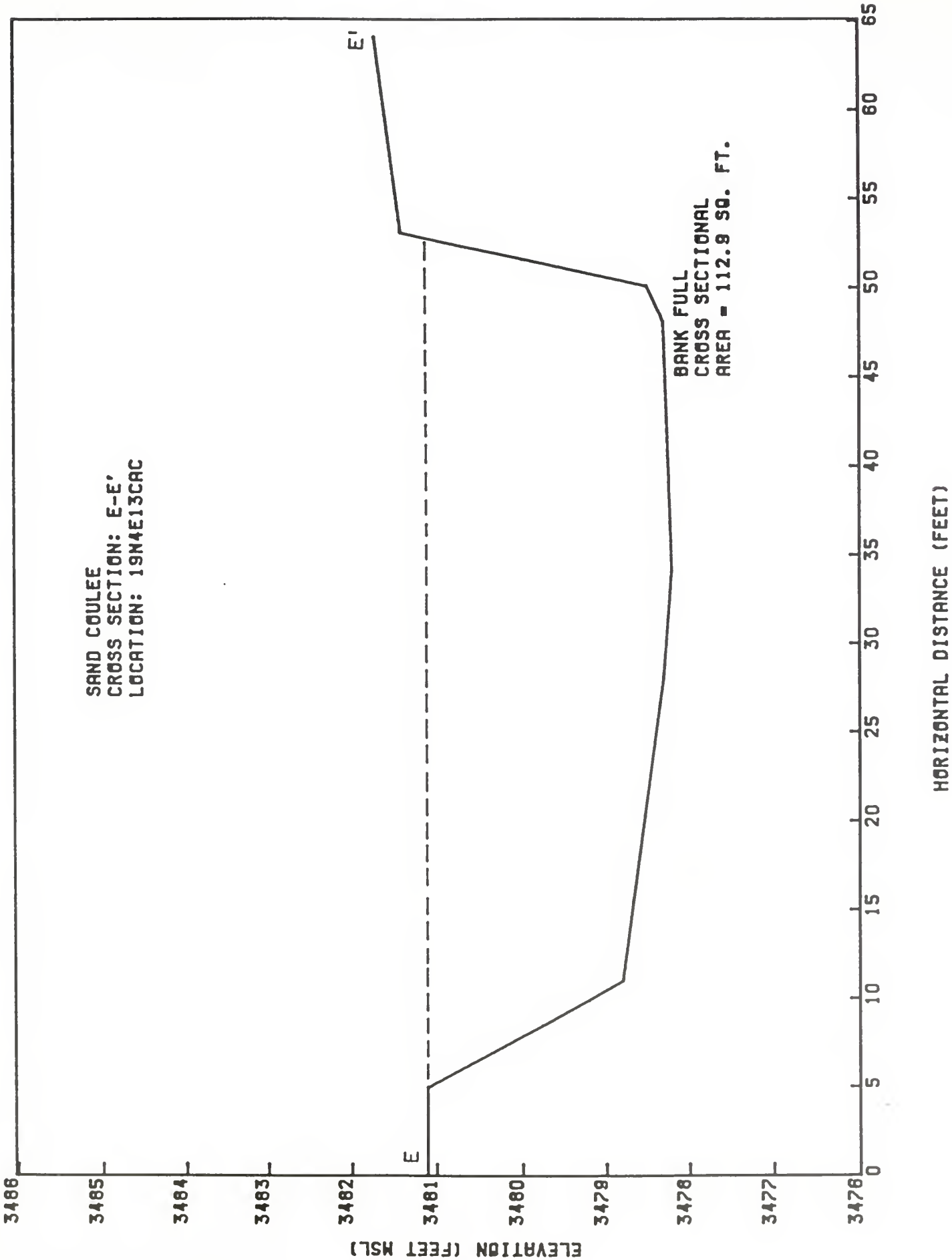


FIGURE 10: SAND COULEE CROSS SECTION E-E'

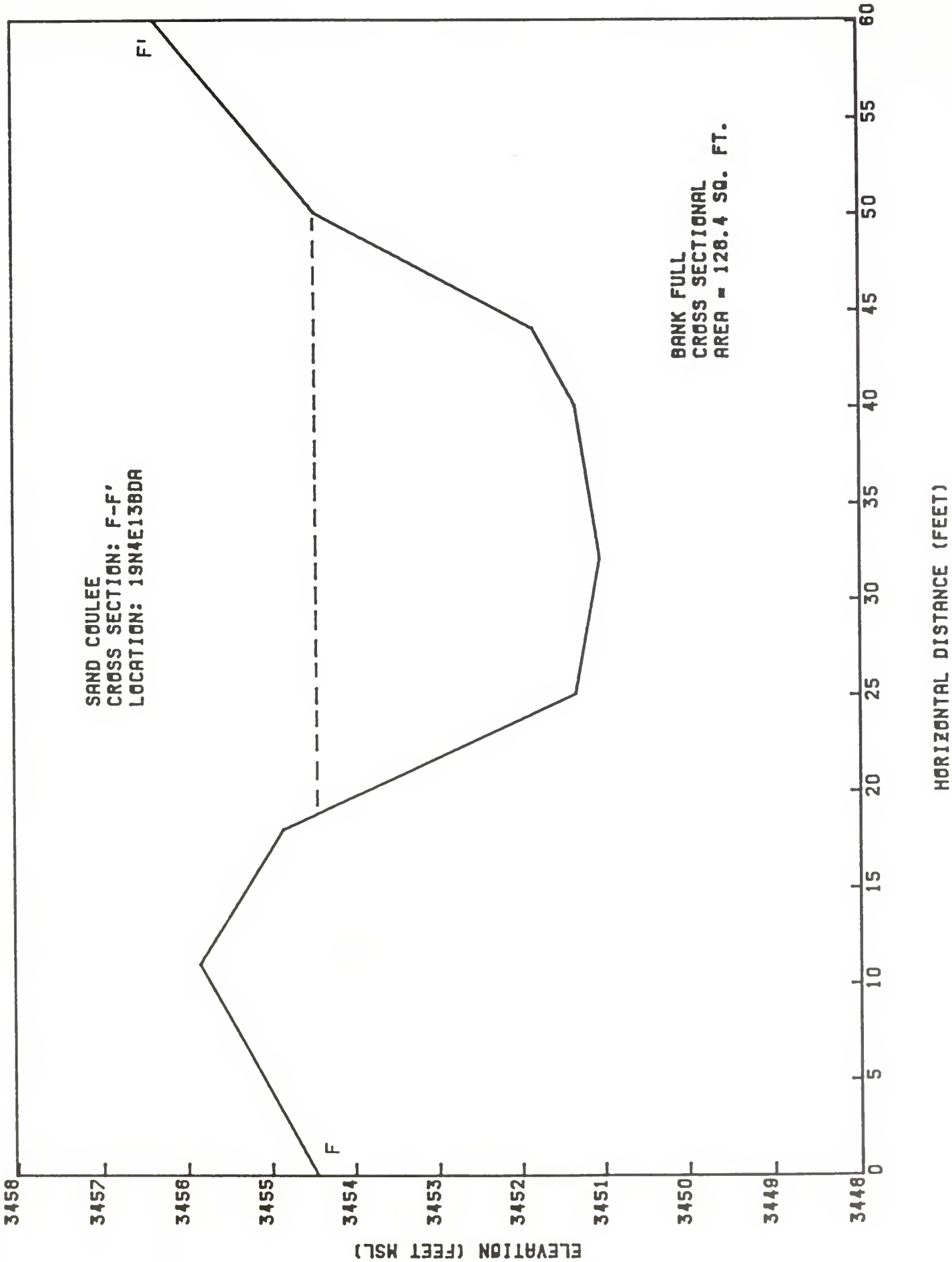


FIGURE 11: SAND COULEE CROSS SECTION F-F'

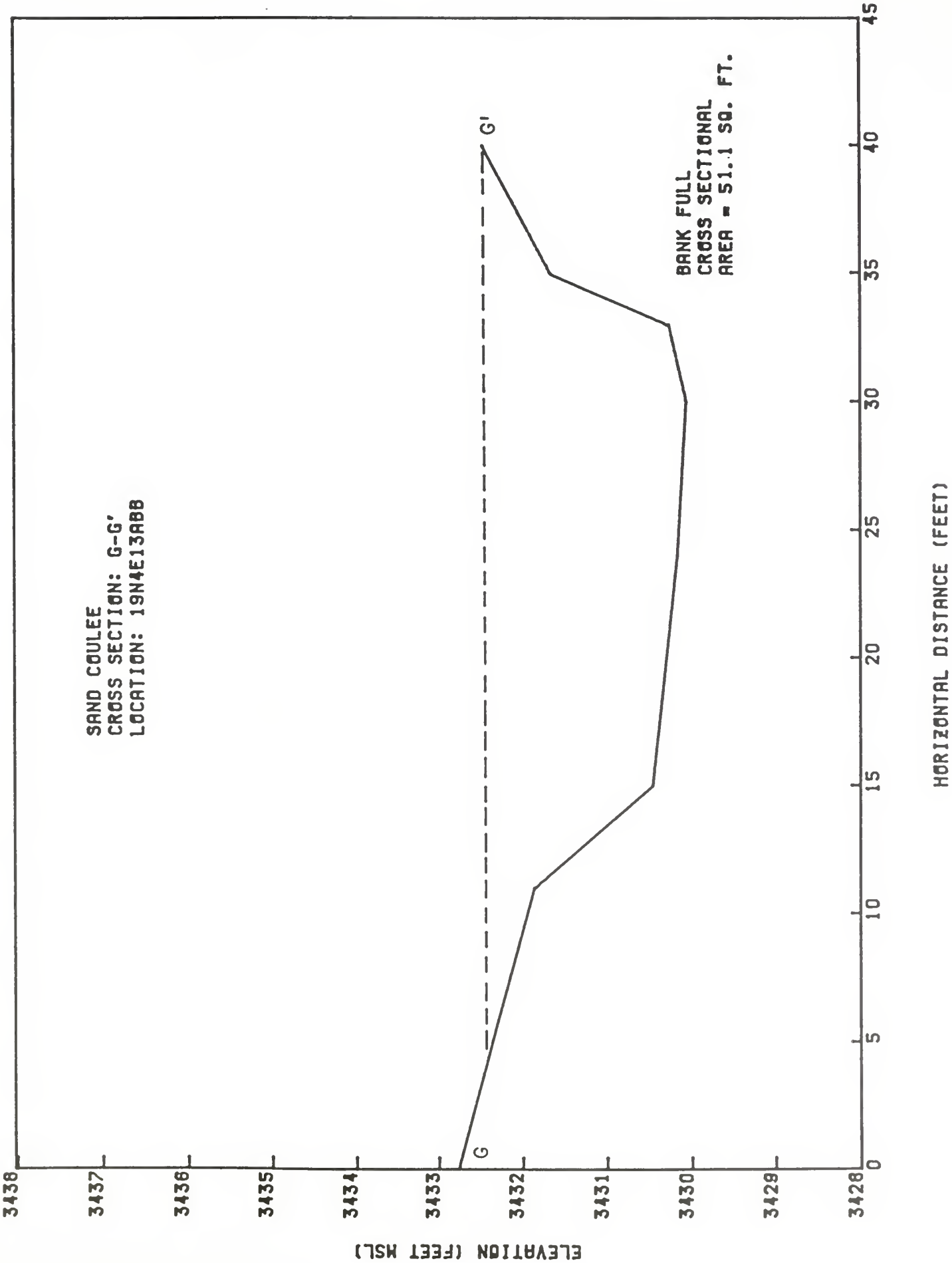


FIGURE 12: SAND COULEE CROSS SECTION G-G'

surface water flow is frequently totally lost to the groundwater system. This loss of flow also contributes to the accumulation of sediment and chemical precipitates.

The channel cross sections (Figures 6 through 12) show a general increase in width in the downstream direction but little change in depth. The furthest downstream cross section (G-G'; Figure 12) has one of the lowest bankfull cross sectional areas and the lowest channel gradient of any of the cross sections. The ability of the channel to transmit high flow is, therefore, restricted in this lower section relative to upper stream segments. The active channel of Sand Coulee Creek below the confluence of Sand Coulee and Sand Coulee Creek just downstream of the study area tends to be much deeper and narrower than the Sand Coulee channel.

Bankfull channel capacity has been calculated utilizing the Manning equation for each of the surveyed cross sections. Channel capacities for the cross sections are shown in Table 5. The smallest channel capacity occurs at cross section G-G' (Figures 4 and 12) where the bankfull capacity is about 230 cfs. A greater flow at this location would flood across Highway 227.

Culvert Evaluation

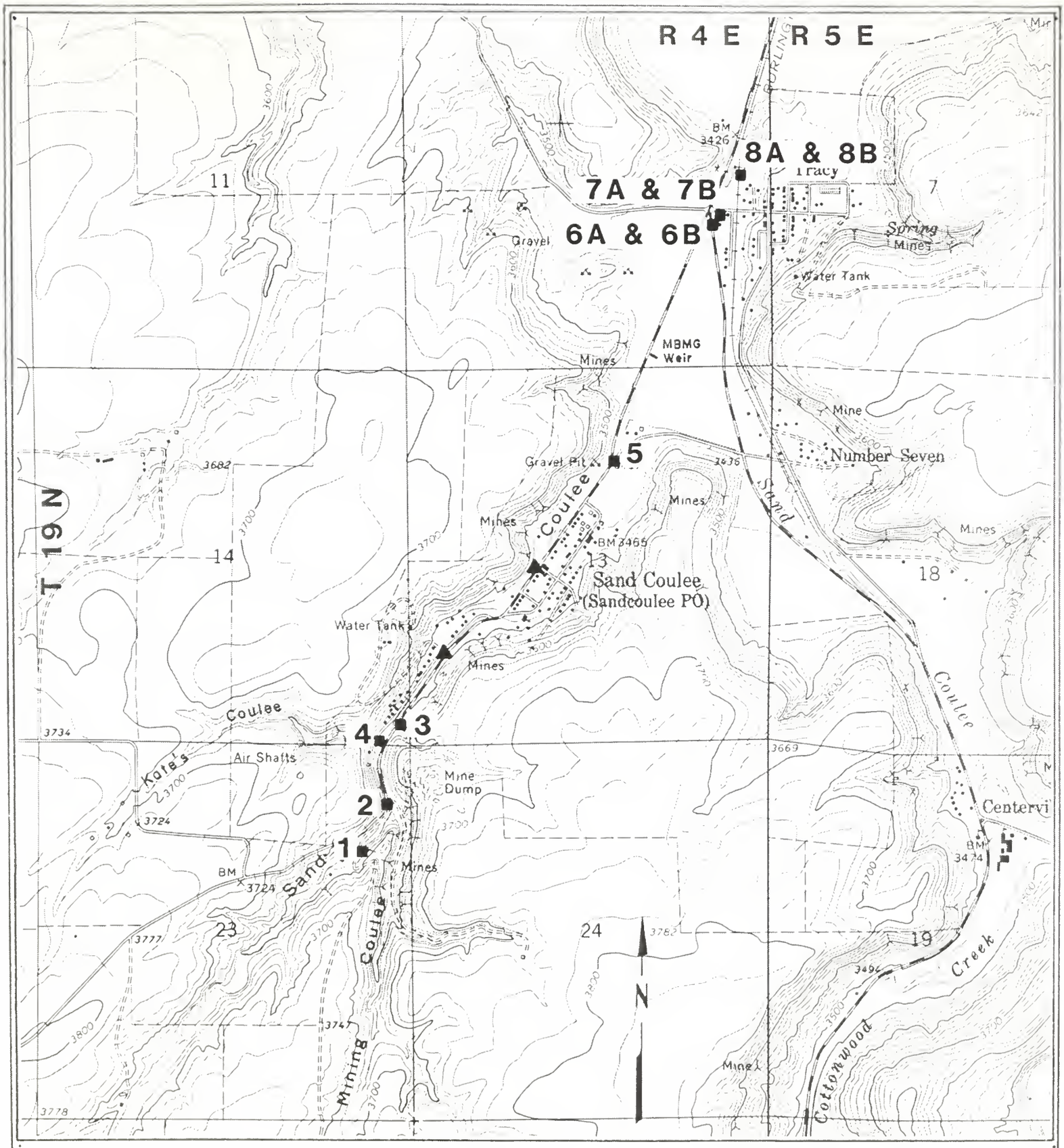
Culverts located on Sand Coulee and Kate's Coulee within the study area were examined as part of this project. Culvert locations are shown on Figure 13. Sand Coulee passes through a total of six culverted road

TABLE 5. MAXIMUM CHANNEL CAPACITY - SAND COULEE

Site	Station	Maximum Flow (cfs)	Maximum Velocity (fps)	Maximum Depth (ft)	Channel Slope (%)	Bank Full Cross-Sectional Area (sq. ft)	Bank Full Wetted Perimeter (ft)
X-Section A-A'	0 + 00	569.3	10.8	5.0	2.62	52.5	21.7
X-Section B-B'	7 + 60	135.7	5.6	1.7	1.86	24.3	21.0
X-Section C-C'	22 + 58	499.9	7.9	5.2	2.04	63.0	34.5
X-Section D-D'	37 + 74	770.5	8.1	4.6	1.11	95.1	31.9
X-Section E-E'	50 + 94	765.3	6.78	2.9	1.10	112.9	49.2
X-Section F-F'	72 + 44	1428.3	11.12	3.4	1.10	128.4	32.5
X-Section G-G'	97 + 74	230.8	4.52	2.4	0.73	51.1	36.8

NOTE: 1) Maximum flow at cross-sections determined by Manning's Equation for Bank Full Channel.

2) Slope is calcualted from upstream station to channel centerline at cross-section.



LEGEND

1 ■ CULVERT LOCATION AND NUMBER

▲ BRIDGE LOCATION

SOURCE OF BASE: U.S.G.S., 1:24000, SOUTHEAST GREAT FALLS, MONT.

FIGURE 13:

CULVERT AND BRIDGE LOCATIONS – SAND COULEE STUDY AREA

HYDROMETRICS Helena, Mt.

crossings, two bridges and one culverted railroad crossing within the study area. Numerous small culverts convey runoff water under side roads but were not examined in detail as part of this project. Kate's Coulee contributes a small continuous flow of acid drainage water to Sand Coulee. This water passes through a culvert just above the confluence of Kate's and Sand Coulees. Culvert locations 6, 7 and 8 near Tracy have two culverts at each site (Figure 13).

Evaluation of each culvert included surveying upstream and downstream inverts to determine grade; survey of road height to determine maximum headwater height; measurement of diameter, and examination of the culvert. Maximum flow capacity, assuming inlet control conditions and maximum headwater height before overtopping the roadway, were calculated using standard nomograph techniques (U.S. Bureau of Public Roads Culvert Capacity Charts, Portland Cement Assoc., 1962). Maximum culvert capacities are listed in Table 6.

Culvert capacities generally increase downstream along Sand Coulee. Culvert capacities are, in all cases, less than the calculated ten year return period peak flow (Parrett-Omang technique) and culvert 1 has insufficient capacity to pass the calculated five year peak flow. Culvert 4 on Kate's Coulee is nearly large enough to pass the twenty-five year peak flow. The relation of culvert capacity to flood flows are shown graphically on Figures 14 and 15. The capacities of the two bridges in the community of Sand Coulee are estimated to exceed the twenty-five year peak flow.

TABLE 6. MAXIMUM CULVERT CAPACITY - SAND COULEE

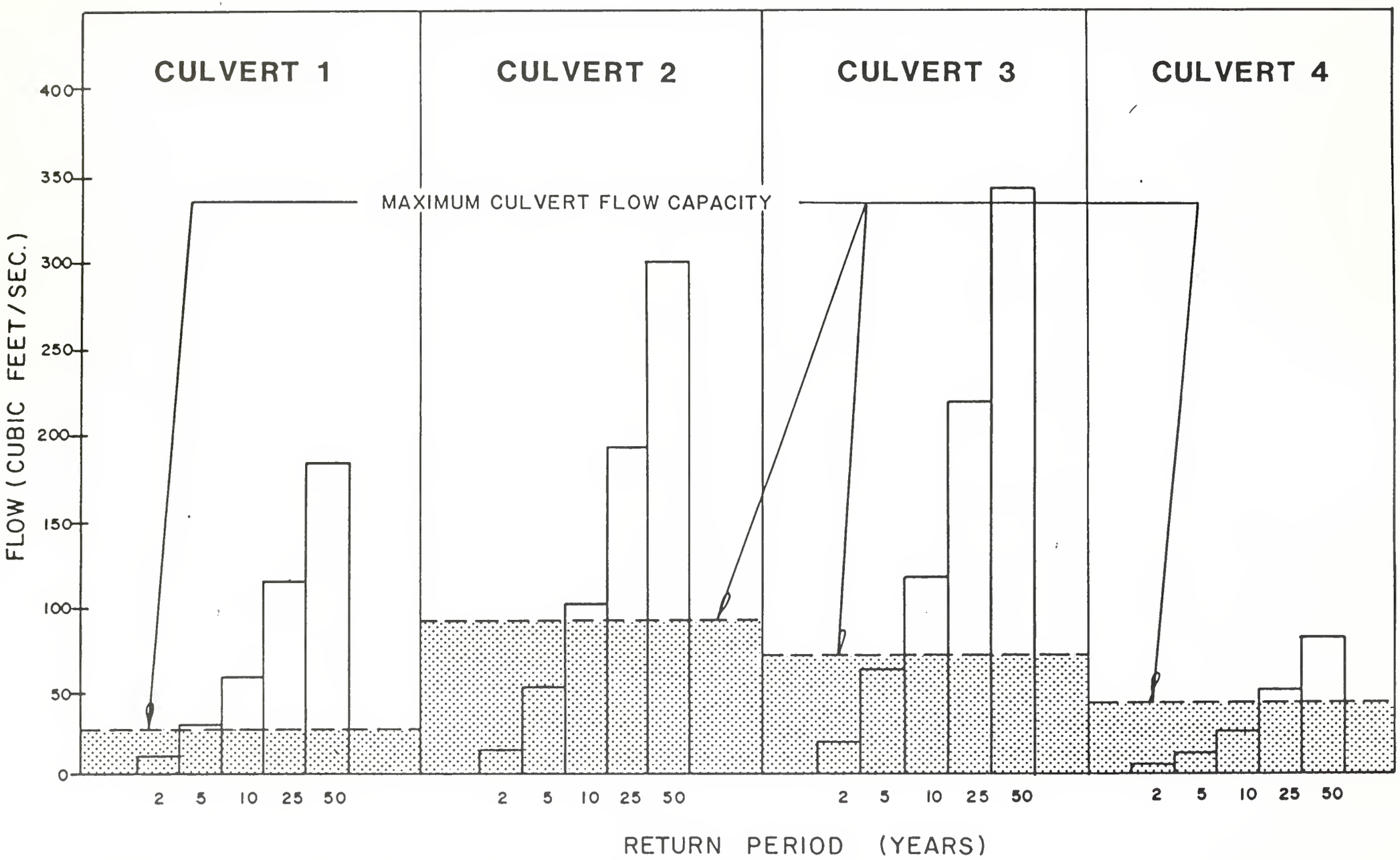
Site	Station	Culvert Type**	Maximum Flow (cfs)		Maximum Velocity (f/s)	Maximum Depth (ft)***
Culvert 1	8 + 83	24" CP	26.0		8.3	5.5
Culvert 2	17 + 65	48" CP	90.0		7.2	5.2
Culvert 3	30 + 06	48" CP	71.0		5.7	4.3
Culvert 4	*	36" CP	43.0		6.1	3.8
Culvert 5	79 + 84	48" CP	110.0		8.8	6.6
Culvert 6A	115 + 51	36" CP	59.0	Site Total	8.4	5.2
Culvert 6B	115 + 51	36" CP	59.0	118.0	8.4	5.2
Culvert 7A	116 + 95	48" CP	97.0	Site Total	7.7	5.7
Culvert 7B	116 + 90	36" CP	50.0	147.0	7.1	5.7
Culvert 8A	124 + 20	36" CP	67.0	Site Total	9.5	6.7
Culvert 8B	124 + 22	36" CIP	71.0	138.0	10.0	7.7

NOTE: Maximum flow through culverts based on inlet control determined using culvert design aids: An application of U.S. Bureau of Public Roads Culvert Capacity Charts, Portland Cement Assoc., 1962.

* Culvert 4 is located in Kate's Coulee near confluence with Sand Coulee

** CP = Concrete Pipe, CIP = Cast Iron Pipe

*** Maximum upstream head before overflowing road



NOTES: 1) FLOW DETERMINED BY PARRETT-OMANG METHOD (USGS, 1981), SEE TABLE

2) CULVERT CAPACITY DETERMINED BY CULVERT DESIGN AIDS: AN APPLICATION OF US BUREAU OF PUBLIC ROADS CULVERT CAPACITY CHARTS, PORTLAND CEMENT ASSOC., 1962

FIGURE 14:

RELATIONSHIP OF CULVERT CAPACITY AND FLOOD FLOWS - CULVERT 1 - 4

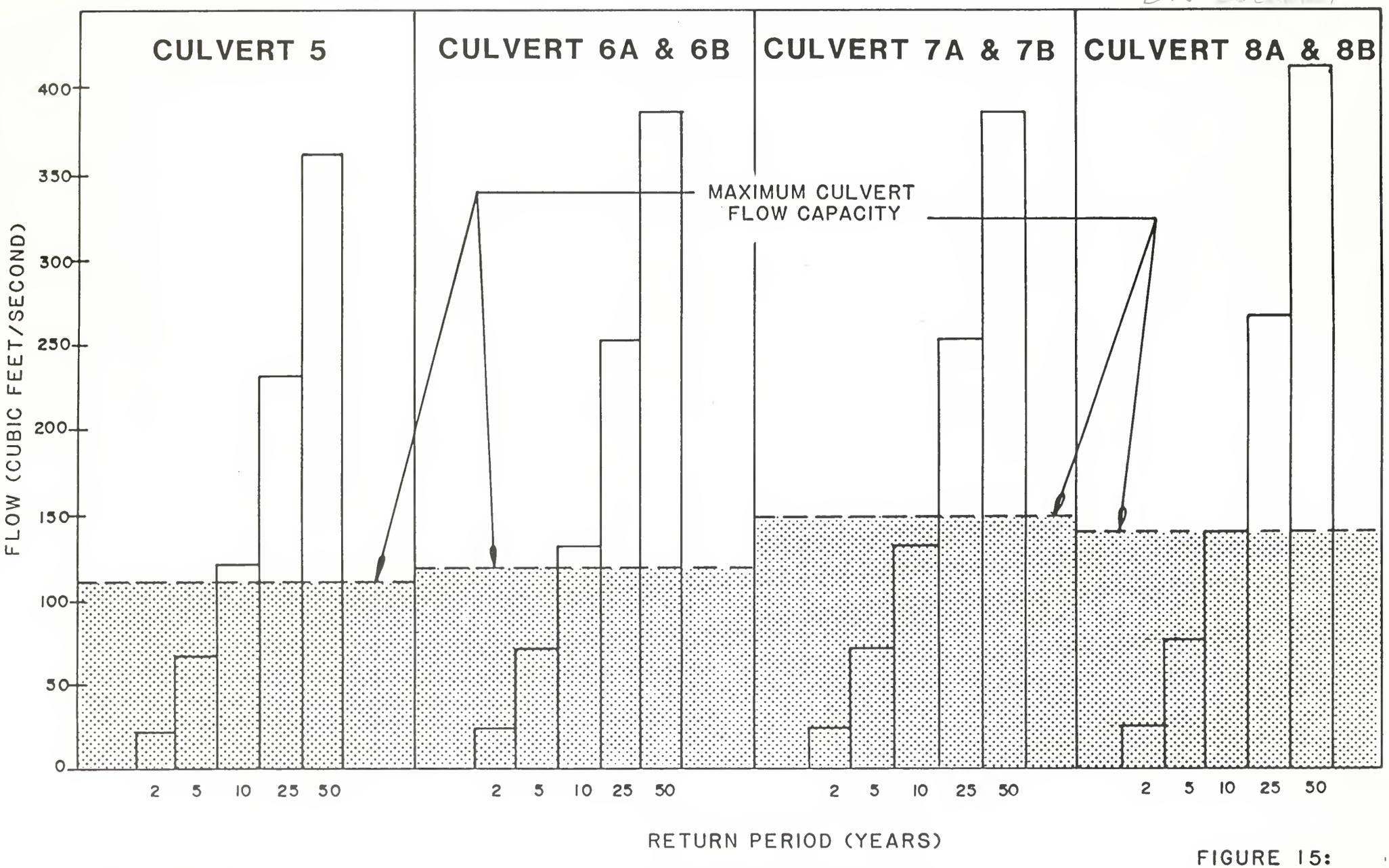


FIGURE 15:

RELATIONSHIP OF CULVERT CAPACITY AND FLOOD FLOWS - CULVERT 5 – 8

NOTES: 1) FLOW DETERMINED BY PARRETT-OMANG METHOD (USGS, 1981), SEE TABLE

2) CULVERT CAPACITY DETERMINED BY CULVERT DESIGN AIDS: AN APPLICATION OF US BUREAU OF PUBLIC ROADS CULVERT CAPACITY CHARTS, PORTLAND CEMENT ASSOC., 1962

All culvert capacities were calculated assuming clean culverts. Several of the culverts were partially filled with sediment and debris during spring 1983. Accumulation of trash and debris in the Sand Coulee channel can result in clogging of culverts during high flows and is a significant problem in this area.

Channel Stability Survey

A stream channel stability assessment has been used to determine the vulnerability of stream channels to physical disturbance as well as the nature and extent of past disturbances. Ten stream reaches were rated for streambank stability (reach refers to a section of stream which has relatively uniform stability rating throughout its length). The entire waterway within the Sand Coulee study area was inspected on foot. Following this examination, the waterway was stratified into reaches, each of which was assigned a number (Figure 16). Stream channel stability within each reach was rated using the methodology of Pfankuch (1978). This is a "scorecard" method which evaluates the stability of the physical and biotic (vegetation) components of stream channel environments. Stream channel features were assigned a value based on scorecard criteria. Summation of these values yielded a score for each respective stream reach which corresponds to a condition class (excellent, good, fair or poor). Table 7 summarizes the stream survey results.

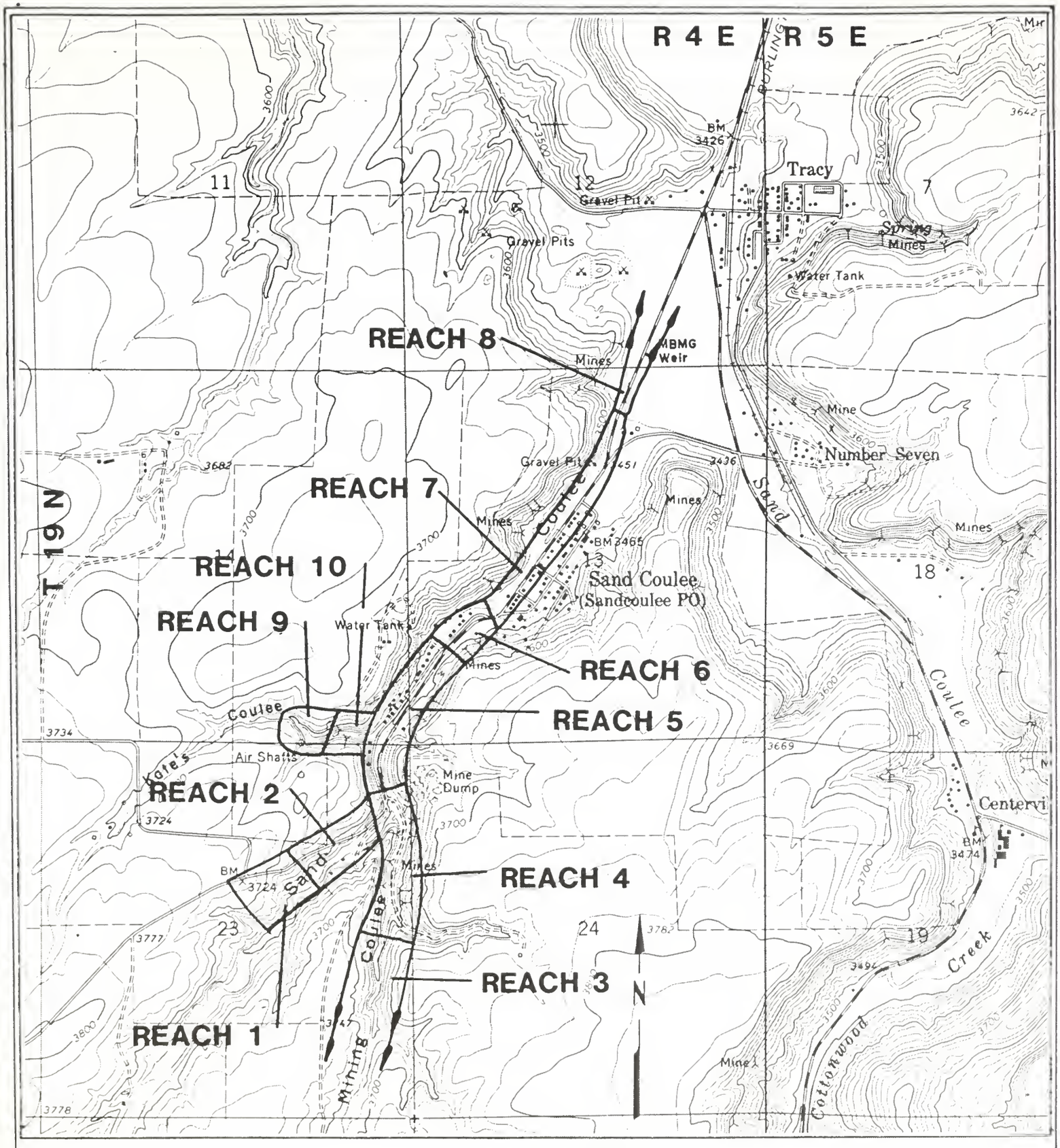
Stream channel stability rating scores increased from the upstream to downstream portions of the study area. In general, this represented an

TABLE 7. STREAM REACH CONDITIONS AND SITE DESCRIPTIONS FOR THE SAND COULEE STUDY AREA

Reach number	Condition	Score	Figure	Site description
1	High fair	77		-native vegetation present -vegetation cover composed of mixture of shrubs and herbaceous vegetation -not influenced by acid drainage -grazed by domestic livestock
2	Low fair	111		-influenced by acid drainage -streambed altered (straightened)
3*	Good	67		-native vegetation present -good coverage by woody riparion vegetation -apparently undisturbed
4 *	**	-		-disturbed (reclaimed garbage dump)
5	Fair	106		-influenced by acid drainage -streambed altered (straightened)
6	Fair	104		-native vegetation present -disturbed by adjacent residential area -influenced by acid drainage
7	Low fair	113		-influenced by acid drainage -streambed altered (straightened)
8	Poor	123		-influenced by acid drainage -stream bed altered (straightened)
9	High Good	43		-native vegetation present -dense cover of woody riparian vegetation composed of several strata (tall trees, low trees high shrubs, low shrubs) -conditions appear very stable
10	Low fair	112		-south bank well vegetated -north bank disturbed, slag piles present(sparsely vegetated) -influenced by acid drainage

* Reach located in Mining Coulee (not part of study area)

** Stream channel disturbed (riprapped), adjacent to reclaimed garbage dump; Stream stability rating not determined.



LEGEND

CHANNEL STABILITY AND VEGETATION STUDY UNITS

NOTE:

REACH 3 & 4 ARE LOCATED OUT OF STUDY AREA

FIGURE 16

STREAM REACH DESIGNATIONS–
CHANNEL STABILITY EVALUATION

SOURCE OF BASE: U.S.G.S., 1:24000, SOUTHEAST GREAT FALLS, MONT.

HYDROMETRICS Helena, Mt.

increase in the influences of acid mine effluent and streambed alteration. Reach nine had the lowest (best condition) rating score, reach eight the highest (poorest condition).

During this survey, precipitates were evaluated as if they were naturally occurring deposits of fine streamborn materials. Hence, high amounts of precipitates and their continued deposition were judged as being undesirable, and thus received high point allocations.

No reach received an excellent rating. This might be attributed to allocation of a large number of points to the stability indicators. However, the rating does provide a relative impression of the range of stream channel conditions existing within the Sand Coulee study area. In addition, the ratings are also indicative of the disturbances which have occurred. The reaches receiving high ratings (Table 7) may be amenable to remedial treatment to improve stream channel conditions.

Riparian Vegetation

The vegetation of the Sand Coulee study area riparian zone was surveyed in order to determine the extent and occurrence of plants in relation to existing environmental conditions. By estimating plant species coverages in natural and disturbed environments, it was possible to determine species tolerances to disturbances. Acid drainage, streambed alteration and toxic slag piles constituted disturbances in the Sand Coulee riparian zone.

Vegetation coverage within the riparian zone was assessed on May 31, 1983. Nine of ten stream reaches designated for the channel stability survey were examined (Figure 16). Reach three was surveyed to provide supplemental information on vegetation coverage in an undisturbed riparian zone. Reach four was located in a sanitary landfill. Since most of the riparian vegetation had been removed by recent bulldozer activity, vegetation coverage was not estimated within reach four. Reaches three and four are located in Mining Coulee; thus, are not part of the study area.

The Damin-Krajina cover-abundance scale was used to estimate vegetation coverage by species (Muller-Dambois and Ellenberg, 1974). In this method, the vegetation stands to be surveyed are canvassed on foot. Simultaneously, a species list is compiled. Following examination of stand vegetation, each species is subjectively placed into a coverage class. These classes are as follows:

Coverage Class	Cover (%)
10	100
9	75
8	50-75
7	33-50
6	25-33
5	10-25
4	5-10
3	1-5
2	1
1	Seldom encountered, insigificant cover
+	Solitary, insignificant cover

No detailed quantitative vegetation measurements are made (i.e. transects are not used). Thus, this method is largely qualitative and semi-quantitive. The resulting cover values are useful as they are based on a larger "sample" area than would be evaluated by any but the most intensive quantitive method of vegetation analysis.

The rationale for the selection of the Damin-Krajina method was that most of the Sand Coulee riparian area had been subjected to some disturbance and vegetation occurrence was rather sporadic. A large number of transects would need to be sampled to accurately measure the occurrence of species.

Individual species coverages for each stream reach are summarized in Table 8. Undisturbed reaches (1, 3, 9) had the best riparian vegetation conditions. Woody riparian species contributed substantially to the vegetation coverage of these reaches. Black hawthorn (Crataegus douglasii), chokecherry (Prunus virginiana), Arkansas rose/woods rose (Rosa arkansana/woodsii) and snowberry (Symphoricarpos albus/occidentalis) coverages ranged from 5 percent to 25 percent in the undisturbed reaches. Herbaceous species which had average coverages exceeding 5 percent were: western wheatgrass (Agropyron smithii), Kentucky bluegrass (Poa pratensis) and Douglas waterhemlock (Circuta douglasii), a poisonous forb. Dense patches of the annual bromegrasses (Bromus japonicus and B. tectorum) were occasionally encountered. It should be noted that coverages in Table 8 represent average values for species coverages within each reach.

TABLE 8. VEGETATION COVERAGE OF THE SAND COULEE STUDY AREA RIPARIAN ZONE[1]

GRASSES

Binomial	Common Name	Reach Number 1	2	3	4	5	6	7	8	9	10	*
Agropyron cristatum	crested wheatgrass				-	3		2				
Agropyron repens	quackgrass				-	4	6					
Agropyron smithii	western wheatgrass	4		4	-				5			
Agropyron spicatum	bluebunch wheatgrass				-	1		2	3			
Agropyron trachycaulum	slender wheatgrass	1			-							
Agrostis alba	redtop				-	1						
Aristida longiseta	red threeawn				-				1			
Bromus inermis	smooth brome				-	3		2				
Bromus japonicus/tectorum	japanese brome/cheatgrass	4	5	2	-	4	3	3	2			✓
Carex spp.	sedge (aquatic)	3	2		-							✓
Dactylis glomerata	orchardgrass				-	2	2	2	2			
Elymus canadensis	Canada wildrye				-				2			
Elymus cinereus	basin wildrye			1	-							
Juncus balticus	Baltic rush		2		-							
Phleum pratense	timothy	2			-							
Poa pratensis	Kentucky bluegrass	8	7	6	-	5		5	6	4	5	✓
Stipa viridula	green needlegrass	1			-							

FORBS

Binomial	Common Name	1	2	3	4	5	6	7	8	9	10	*
Achillea millefolium	western yarrow	2		2	-							
Artemisia ludoviciana	cudweed sagewort	1			-							
Balsamorhiza sagitatta	arrowleaf balsamroot	1		1	-							
Cerastium arvense	field chickweed	1		1	-							
Chenopodium album	lambsquarters goosefoot				-						+	
Cicuta douglasii	Douglas waterhemlock	4	3	5	-	2	4				4	
Cirsium undulatum	wavyleaf thistle	1		1	-							
Cirsium vulgare	bull thistle	1			-	2	2				3	
Convolvulus arvensis	field bindweed		1		-							
Cynoglossum officinale	houndstongue	4	2	1	-							
Epilobium spp.	fireweed		1		-	3				3		
Erodium cicutarium	filaree	1		1	-							
Galium spp.	bedstraw	1			-	3						
Geranium viscosissimum	sticky geranium	1			-							
Glycyrrhiza lepidota	wild licorice				-	1			1		2	
Grindelia squarrosa	curlycup gumweed		1		-			1				
Helianthella uniflora	oneflower helianthella			1	-							
Heracleum lanatum	cow parsnip	1			-							
Lactuca serrulata	prickly lettuce				-				5			
Lepidium densiflorum	prairie pepperweed	3	1	1	-							
Lepidium perfoliatum	clasping pepperweed				-	2						
Medicago sativa	alfalfa				-		1					
Melilotus officinalis	yellow sweetclover				-	3	2					
Moss	--				-							
Polygonum spp.	knotweed				-	3		4	5			

Forbs con't

Binomial	Common Name	1	2	3	4	5	6	7	8	9	10	*
Potentilla spp.	cinquefoil	1			-							
Psoralea spp.	Scurípea				-	+						
Ratibida columnifera	prairie coneflower	1			-							
Rheum rhaponticum	rhubarb				-	+						
Rumex crispus	curly dock		1		-		2					✓
Sisymbrium loeselii	smallpod tumblemustard	2	3		-				2			
Solanum dulcamera	climbing nightshade				-					2		
Taraxacum officinale	dandelion	2	2	1	-	1						
Thermopsis rhombifolia	prairie thermopsis	1			-	1		2	2			
Thlaspi arvense	fanweed	1		1	-	1						
Tragopogon dubius	salsify			1	-	1			3			
Urtica dioecia	stinging nettle	1			-	2						
Vicia americana	American vetch	1		1	-							
Viola adunca	hook violet	1			-							

HALF SHRUBS, SHRUBS AND TREES

Binomial	Common Name	1	2	3	4	5	6	7	8	9	10	*
Amelanchier alnifolia	serviceberry		+		-	1				2	3	
Crategus douglasii	black hawthorn	3		5	-							
Fraxinus pennsylvanica	green ash				-	2	3	3			3	✓
Lonicera tartarica	tartarian honeysuckle	+			-							
Populus deltoides	plains cottonwood	2			-	2	5	2		5		
Populus tremuloides	quaking aspen				-						5	
Populus trichocarpa	black cottonwood	2	3	3	-	1				6	4	✓
Prunus virginiana	chokecherry	5	3	7	-	3		2		8	5	
Rhus trilobata	skunkbush sumac	1		+	-	+					2	✓
Ribes aureum	golden current	+			-					2	3	
Ribes cereum	squaw current	2			-							
Ribes setosum	redshoot gooseberry	2			-					5		
Rosa arkansana/woodsii	rose	4	3	5	-	3		2	3	3	3	
Salix spp.	willow		+		-	1	3			5	3	✓
Symphoricarpos albus/ occidentalis	snowberry	6	3	4	-	3	3		3		4	✓
Xanthocephalum sarothrae	broom snakeweed	2			-							

1 Numbers opposite each species are coverage class designations for respective stream reaches.

* ✓ Indicates species was observed growing within the high water marks of the stream (may indicate some degree of acid tolerance).

\- Not surveyed.

Shrubs in natural plant communities usually occur as aggregates or "clumps"; rarely are they randomly or evenly distributed (Pielou, 1960). Thus, in this survey, shrub patches were encountered which often had coverages exceeding 50 percent (some to 100 percent). However, within any given reach, the areas between shrub patches were often devoid of, or sparsely covered by shrubs. Thus, the coverage values indicated for woody riparian species in any reach are an average of shrub "clump" coverages and intershrub areas which are devoid of, or sparsely covered by shrubs. Realization of natural aggregation of shrubs in the field is of particular utility. Efforts to reestablish shrubs in the field should be conducted in a manner which is suggestive of this natural "clumping".

Reaches which were disturbed by acid mine effluent or streambed alteration (2, 5, 6, 7, 8, 10) typically had reduced coverage by woody riparian species. Notable exceptions were reaches six and ten. Reach six was located in a residential area. Coverage of woody riparian vegetation in this reach was substantial where not disturbed by local residents. Reach ten was represented by two distinct communities. The south bank was well vegetated by a number of herbaceous and woody species, and was similar in appearance to the undisturbed reaches. The north bank was sparsely vegetated and woody riparian species occurred sporadically. Reach ten borders Kate's Coulee and both banks are exposed to acid effluent from SCM 6. However, while the soils of the south bank were undisturbed, those of the north bank contained frequent deposits of slag materials. These slag piles appeared to be an

unsuitable substrate for plant growth and were sparsely vegetated. It also appeared that the acid effluent either exerted a minor influence, if any, on the vegetation of the south bank, or that this vegetation was obtaining water from sources other than the creek.

Several species appeared to be suitable for revegetation of acidic streambanks. Green ash (Fraxinus pennsylvanica) was observed in many of the disturbed stream reaches. It was reproducing vigorously via "suckers" (rhizomes) in reach five. Other species that are apparently able to live under acidic conditions were: Quackgrass (Agropyron repens), Kentucky bluegrass, chokecherry, rose, snowberry, and plains cottonwood (Populus deltoides). These species apparently have developed some tolerance to acidic conditions. They are, however, not the only species suitable for revegetation particularly if soil amendments are used in reclamation.

GROUNDWATER

Information on wells and springs has been gathered by Hydrometrics (1982) and MBMB (1983). Two additional wells (both currently unused) were identified during 1983. A listing of wells within and adjacent to the study area is presented in Table 9 and shown on Figure 17. A total of ten wells are located within the study area. Most of these wells are used for domestic or stock supply. The community of Sand Coulee obtains its public water supply from two wells apparently completed in Kootenai and upper Morrison sandstone units.

High Water Table Areas

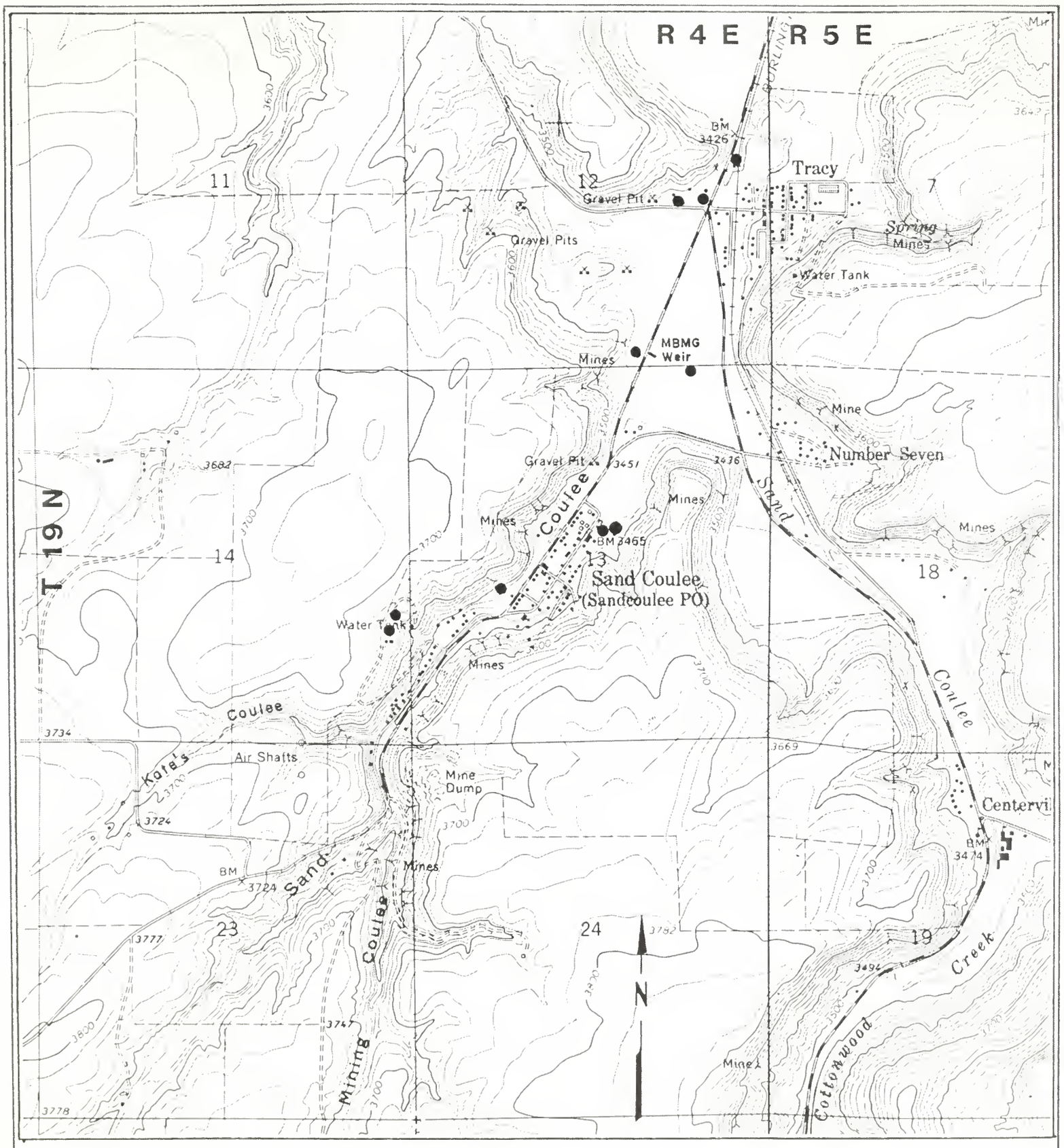
Several areas of high groundwater cause springs, seeps and some water problems in basements. The Kootenai basal sandstone is exposed in the coulee walls throughout the study area. Discharge as springs and seeps occurs from the east facing coulee wall along the southern portion of the town of Sand Coulee. Several residents obtain private water supplies from developed springs south of SCM 5. Seepage of AMD from SCM 6 is evident along the base of waste pile No's 15, 16, 17 and is reported to have caused seepage in M. Surmi's basement.

Shallow water table along Sand Coulee and Kate's Coulee is evidenced by the riparian vegetation and depth of water in wells and excavations. Mrs. P. Romanchuk has a continuous acid groundwater and inflow to her basement. Romanchuk's basement is excavated below the present alluvial water table. Although the problem has been occurring for a number of

TABLE 9. WELL INVENTORY - SAND COULEE STUDY AREA

Location	Total Depth (ft)	Yield (gpm)	Static Water Level (ft)	Aquifer	Owner
19N04E12ADDC	136	15	115	Morrison Sandstone	Gordon Mindt
19N04E12DBAA	158	-	-	Madison Limestone	Richard Kajala
19N04E12DABA	131	15	114	Morrison (?)	Evelyn Lyman
19N04E12DCCD	147	-	110	-	Renee Lynch (Abandoned)
19N04E13AABB	168	-	-	Madison Limestone	Renee Lynch
19N04E13ACCB	328	8	165	Madison Limestone	George Kavulla
19N04E13CB*	-	-	28		-
19N04E13CBAD	60	-	-	Alluvium (?)	Bill Tesinsky (Abandoned)
19N04E14DADA	210	-	-	Kootenai and Morrison	Sand Coulee Water Users
19N04E14DADC-2	210	60	150	Morrison Sandstone	Sand Coulee Water Users
10M-4E13ACC	287	14	224	Madison Limestone	Theodore Mrochen

Source: After MBMG (1983) and Hydrometrics (1982) with additions.



LEGEND

● GROUNDWATER WELL

SOURCE OF BASE: U.S.G.S., 1:24000, SOUTHEAST GREAT FALLS, MONT.

FIGURE 17

LOCATION OF WELLS IN THE VICINITY OF THE SAND COULEE STUDY AREA

HYDROMETRICS Helena, Mt.

years, it may be in part attributable to stream aggradatation and a raising of the alluvial water table. Insufficient data exists to evaluate the possibility of a higher alluvial water table due to AML-induced stream aggradation.

Groundwater Contamination

Contamination of the shallow Sand Coulee alluvial aquifer has been reported by Hydrometrics (1982) and MBMG (1983). Of the ten wells reported to exist in the study area, most are completed in Jurassic sediments of the Morrison formation or in Madison limestone. Tesinsky's abandoned alluvial well and possibly Lyman's well and Lynch's abandoned well have been affected by acid mine waters. Indirect evidence indicating contamination of Lyman's well in Jurasic sediments include the high total dissolved solids content and high sulfate concentration (MBMG, 1983). Water quality data from the abandoned Lynch well includes only field pH and conductivity of a grab sample collected in July 1983 (pH = 6.9, conductivity = 2380 umhos/cm). These data suggests the possibility of acid mine water contamination. There is insufficient information available to conclude that leakage from Sand Coulee alluvium has affected deep bedrock aquifers in this area. Sand Coulee alluvium is apparently contaminated by AMD throughout the study area below SCM 2.

MINING DISTURBANCES

WASTE PILES

In the Sand Coulee area there are numerous waste dumps associated with abandoned coal mines. These waste dumps, or slack piles as they are commonly referred to, range in size from a few cubic yards to over 30,000 cubic yards in volume. The material in the waste dumps varies in size from fine-grained silt-sized material to cobble-size chunks of waste coal and overburden. In addition to poor quality waste or slack coal, many waste dumps contain sandstone or shale overburden material and ruins of abandoned mine facilities.

For the purpose of this study, dumps of less than 25 cubic yards were considered relatively insignificant to the total volume of waste material and were not surveyed to accurately determine dump volumes. There are 30 waste dumps with estimated volumes of more than 25 cubic yards which were surveyed by Robert Peccia and Associates to accurately determine volumes of waste material. Standard survey techniques using cross sections and areas were used to determine volumes of these sites. Figure 18 illustrates the level of detail used to survey a typical waste dump. The survey work was completed in late May 1983 and calculated material volumes are shown on the waste dump inventory (Table 10). The site numbers in Table 10 correspond to the numbered sites shown on Exhibit 1. Table 4 provides cross referenced site designations for AMDs with previous studies of this area. Sites 3 and 8, owned by Ernest Chartier, consist of clinker material that is

TABLE 10. SAND COULEE WASTE DUMP INVENTORY

Site No.	Location	Volume (cu. yd.)	Maximum Length (ft.)	Maximum Width (ft.)	Approx. Maximum Depth (ft.)	Remarks
1	19N4E23ACD	207	70	53	5.5	
2	19N4E23ADB	24	26	30	3.5	
3	19N4E23ACA	*				Not to be Disturbed
4	19N4E23ADB	32	30	58	2.0	
5	19N4E23ADB	16	30	31	2.0	
6	19N4E23ADA	277	280	36	3.7	
7	19N4E24BBB	*				Out of Study Area
8	19N4E23AAA	*				Not to be Disturbed
9	19N4E14DDD	5,372	115	240	19.5	AMD SCM 5, open Adit, Borders Stream Channel
10	19N4E14DCC	262	100	65	4.0	Open Adit
11	19N4E23ABB	594	95	62	13	Borders Stream Channel
12	19N4E14DDD	277	135	44	4.2	
13	19N4E14DDD	163	108	56	3.0	
14	19N4E13CCB	2,302	120	150	13.5	
15	19N4E13CCA	32,481	200	650	19.5	Open Adit
16	19N4E13CBD	3,893	295	160	12.5	AMD SCM 6, Impact to Private Home
17	19N4E13CAC	2,927	270	117	8.5	
18	19N4E13CBA	28	30	30	3.4	Active Dump, Open Adit
19	19N4E13CBA	94	60	38	3.5	AMD SCM 11, Open Adit
20	19N4E13CBA	289	150	56	4.5	Borders Stream Channel
21	19N4E13BDD	74	55	45	3.3	
22	19N4E13BDD	613	125	107	5.5	
23	19N4E13BDA	2,710	160	205	9.0	
24	19N4E13DBB	21	70	44	0.7	Erosion Problem
25	19N4E13ACC	131	115	82	1.3	Erosion Problem
26	19N4E13ACC	2,907	183	145	11.4	Impact to Land
27	19N4E13BAA	4,014	210	112	20.5	Open Adit, Intermittent AMD
28	19N4E13ABB	400	140	61	4.7	
29	19N4E12DBB	625	120	95	8.4	Impact to Land
30	19N4E12DBB	453	230	68	6.5	

Total Volume of Surveyed Mine Dumps = 61,186 yds^3

* Dump Volumes Not Surveyed as Part of This Study

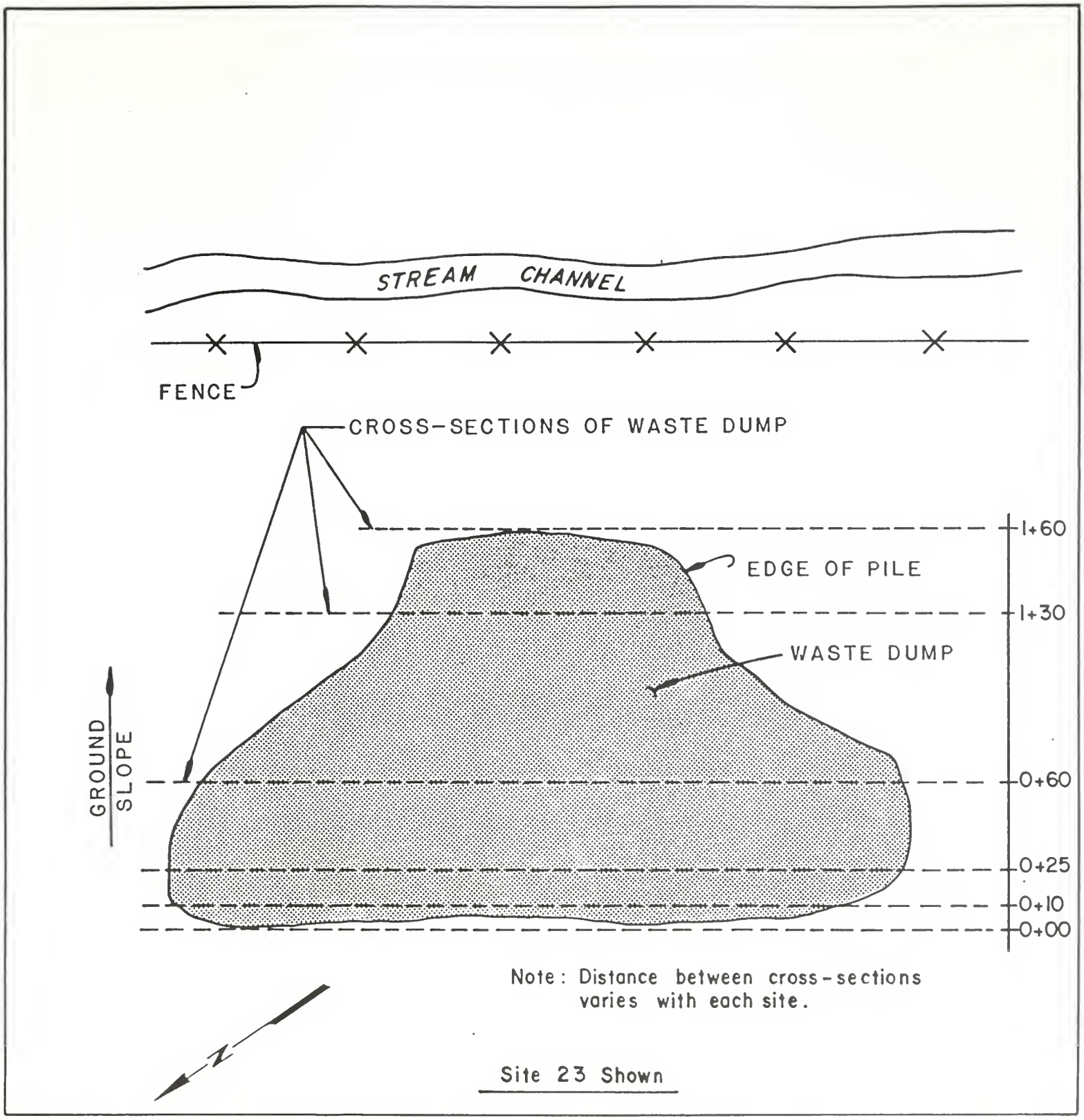


FIGURE 18

TYPICAL SURVEY METHOD OF ABANDONDED MINE WASTE DUMPS IN THE SAND COULEE STUDY AREA

locally used for surfacing roads. Mr. and Mrs. Chartier would like to have these two sites left as they are. Site 7, also owned by the Chartiers and known as the "Finger Pile", is out of the study area but is included on Exhibit 1 as a reference point. The volume of these three large cinder piles is not known. From the inventory, it can be seen that the majority of the waste volume is contained in site 15. Site 15 is located near the center of the community of Sand Coulee on the southwest side of the main street and is affected by the discharge from SCM 6.

There are several problems associated with waste dumps in the Sand Coulee area. One of the most significant problems is the erosion of waste materials into the drainages and onto private property including agricultural lands and private yards. Waste dumps 9, 11 and 20 actually form portions of stream banks during normal and high flows, thus adding some waste material to the stream. Erosion of waste material onto agricultural land or private yards is most evident at sites 15, 16, 17, 23, 24, 25, 26, 27, 29 and 30.

SUBSIDENCE

Subsidence areas are located in many places on the hills around Sand Coulee where abandoned underground mine workings have collapsed. Subsidence depressions within the study area vary in depth from a few inches to about 15 feet. Surface expression of most subsidence is evident as a smooth concave shape with a well vegetated surface.

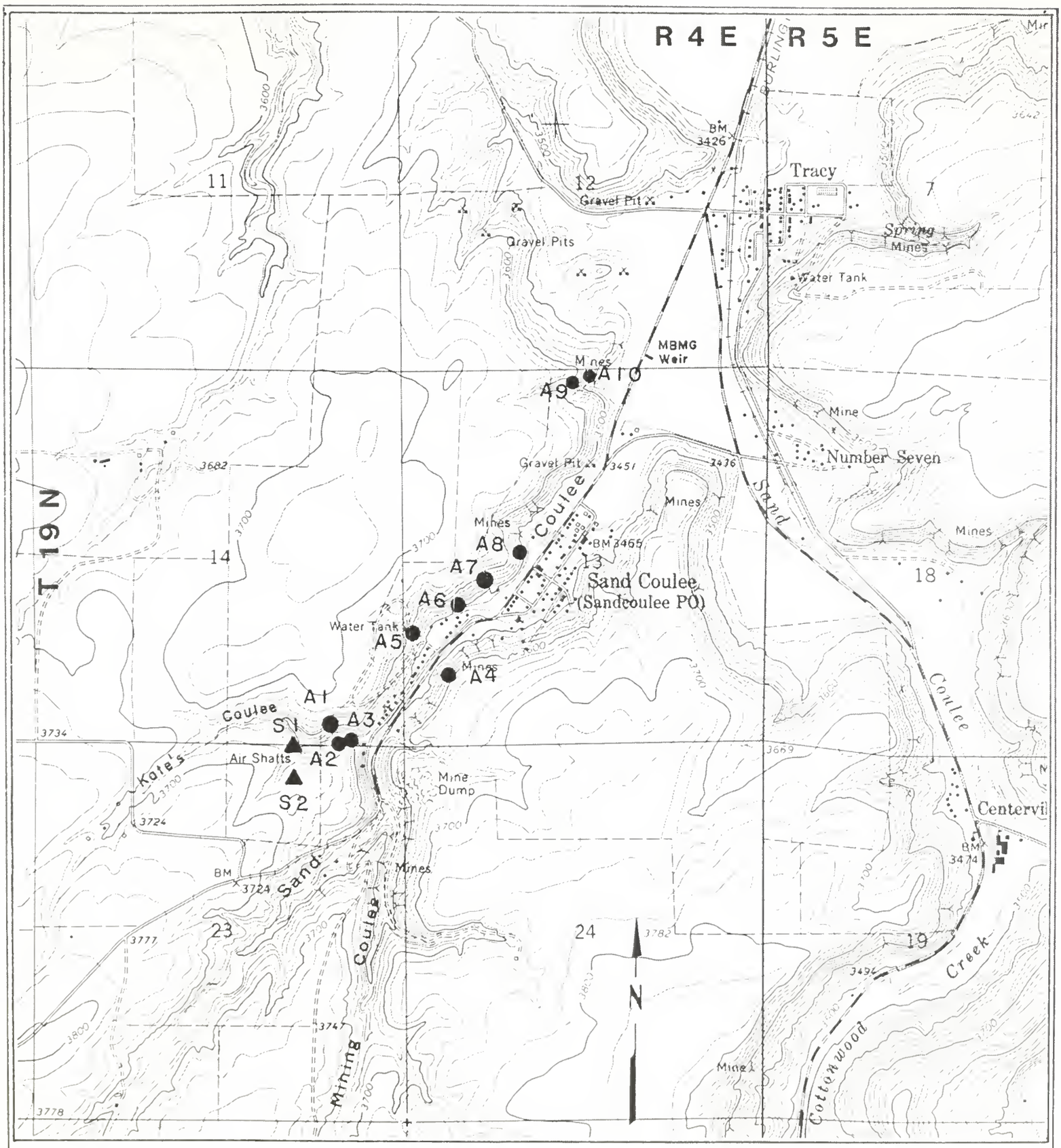
However, there are some areas that have a surface of fractured sandstone.

Subsidence areas were mapped by Associated Surveys, Inc., Billings, Mt. using air photos and stereo compilation on the original base map. These areas were field checked in April and May 1983 by Hydrometrics. Subsidence areas are shown on Exhibit 1. Few problems or hazards are related to subsidence, although these closed depressions may contribute increased infiltration to underlying mine workings.

ADITS

Mine adits within the Sand Coulee study area are located at an elevation of about 3525 feet on both sides of the Sand Coulee drainage. The adits were field checked in April and May 1983 by Hydrometrics and classified as: 1) open, 2) collapsed and 3) discharging. Classification of adits as open or collapsed, focuses on safety hazards and availability for backfilling. An open adit is one large enough that a person could get inside without any excavation. Within the study area there are 10 open adits; 6 acid mine discharges; and 22 collapsed adits as located by Hydrometrics. Locations of all adits are on Exhibit 1 and open adits are on Figure 19.

One open adit (number A6) is presently used for access to a private mine. The adit is located near waste dump site 18 and is owned and worked by Hobert Feller. The adit has wooden doors that close off the



LEGEND

● ADIT LOCATIONS WHICH ARE OPEN

▲ AIR SHAFT LOCATIONS

SOURCE OF BASE: U.S.G.S., 1:24000, SOUTHEAST GREAT FALLS, MONT.

FIGURE 19

LOCATION OF OPEN ADITS AND AIR SHAFTS – SAND COULEE STUDY AREA

HYDROMETRICS Helena, Mt.

entrance preventing access and virtually eliminating any public safety hazard.

An open adit is located in a small drainage near the south end of town, just east of the Sand Coulee water tank at 19N04E13CBC. This adit is not in close proximity to a waste dump or any other mining disturbance. Local residents report that children sometimes play around and inside of the mine. This situation is a potential safety hazard due to the poor condition and unstable nature of the adit.

The remaining seven open adits are located adjacent to waste dumps. There is an open adit located near dump site 10, site 15, site 19, one approximately 200 feet southwest of site 21 and two adits near dump sites 27 and 9 (Exhibit 1). Each of these open adits is a possible safety hazard.

The 22 identified collapsed adits within the study area (Exhibit 1) are less hazardous than either the open adits or the acid drainage. However, the possibility that the adit or mine shaft may collapse further still poses some threat to safety.

AIR SHAFTS

There are two vertical air shafts located inside the study area that were used to ventilate the underground coal mines. The air shafts are located in 19N04E25ABA as shown in Figure 19. A Hutterite Colony has recently acquired ownership of this property from Frantzich's. The

northern most shaft is about 10 feet by 10 feet and has an estimated depth of 30 feet. At one time there was a fence around the shaft but, presently, the fence is broken down and the shaft is not marked.

The southern air shaft (10 feet by 10 feet opening) has caved and is partly filled with trash. The actual depth is unknown and it is likely that the cave in and trash form a bridge filling only part of the shaft. This shaft has a fence around it that is in fair condition.

Both air shafts could be hazardous to livestock and people.

Prioritization of AML Problems

AML-related disturbances in the Sand Coulee area create a variety of problems including safety hazards, soil and water contamination, property damage and aesthetic degradation. Priority should be given to mitigating health and safety hazards in developing a comprehensive reclamation plan for the Sand Coulee area. Although assessing health and safety hazards with limited data is to some extent subjective, the existance of open adits and air shafts appears to present to greatest safety hazard in the study area. Other problems requiring special consideration in reclamation planning include: AMD contamination of private property, AMD contamination of wells, AML-related channel degradation causing flooding, deposition of mine waste material on private property, sediment deposition from waste dumps into stream channels, chemical precipitates from AMD in stream channels, blowing dust, lost forage production and aesthetic problems with mine waste

dumps. Specific recommendations for reclamation of the AML disturbances are presented in the Reclamation Alternatives section of this report. Sealing off access to open adits, plugging air shafts and controlling AMD drainage and sediment from waste dumps are of high priority.

Improvements to the Sand Coulee stream channel to control flooding and improve bank stability were commonly mentioned by local residents. Channel improvements should be considered a lower priority than the safety hazards or damage to private property but are of considerable concern to local residents.

RECLAMATION ALTERNATIVES

Reclamation or mitigation alternatives for AML-related disturbances within the Sand Coulee study area are outlined in this section. Alternatives are presented for each "problem" and approximate costs are estimated for each alternative. Where one alternative has significant cost, environmental or logistical advantages, a reclamation recommendation is made. In several cases, sites (particularly waste dumps) have been grouped and a single reclamation alternative is applicable to the sites individually or as a group. A summary of "problems" and site specific recommended solutions is included for each general catagory of AML disturbance. Cost estimates are approximate and are of value in comparison of alternatives. General discussion of soil amendment and revegetation methods are discussed in Appendices D and E. Detailed reclamation plans, costs and engineering specifications will be developed in Phase II of this project.

ADITS

Open adits are a major safety concern in the study area and acid mine discharges from both open and collapsed adits cause significant damage to hydrologic systems and private property. Access to open adits can be controlled by collapsing the portals by blasting, filling rubble into the open portals or constructing doors or bulkheads.

Blasting or filling are more permanent solutions than construction of doors or bulkheads. Blasting involves setting charges and blasting to

cave roof and wall materials to block the entrance. Blasting may not be appropriate near occupied dwellings or where adjacent property could be affected. Adit plugging by blasting also would not be appropriate for discharging adits due to possible increase in water pressure and failure of the plug or seepage from other adit outlets. After blasting, caved material may have to be moved with a bulldozer to effect complete closure and clean up the site. Closure of adit openings can also be accomplished utilizing adjacent or hauled in fill material consisting of large sandstone rubble. This operation would involve a front-end loader or dozer to place the material and truck haulage if suitable material is not available near to the portal. Filling would be most effective at sites with good access for equipment and where fill material is available immediately adjacent to the open adit.

Construction of doors or bulkheads would allow future access to open adits and would not place additional rock in contact with acid mine water. Also the bulkheads can be designed to allow continued drainage of water from wet adits. Wooden doors or wooden or concrete bulkheads would not be permanent solutions but could be designed to last many years. Treated wooden structures would have a significant life expectancy in contact with acid water and would be appropriate for restricting access to discharging adits such as SCM-5. Concrete plugs or bulkheads would be an essentially permanent solution to closing dry adits.

Reclamation of collapsed adits or adits closed by filling or blasting would involve grading adjacent cover material over the collapsed portal, addition of topsoil, fertilization and seeding. This would provide a vegetated slope, but could not be easily accomplished on steep slopes. Because of the small areas and limited access, reclamation of adits would probably be by hand labor except the regrading and spreading operations. The following outlines adit closure and reclamation alternatives.

ADIT CLOSURE AND RECLAMATION ALTERNATIVES

Alternative	Advantages	Disadvantages	Approximate Cost Range
Blasting Portal Closed	Permanent Solution	Not applicable near residences. May require clean-up with dozer. Not applicable to discharging adits.	$1000 - 1500
Fill Portal with adjacent material	Permanent Solution	Not applicable to areas with steep slopes or poor access or to discharging adits.	500 - 800
Wooden Bulkhead	Low Cost allows re-entry	Temporary Solution Allows mine drainage.	700 - 1200
Concrete Bulkhead	Permanent Solution	Not applicable to areas with difficult access. Not cost-effective in contact with AMD	1400 - 2100
Regrading and Revegetation	Decreases visual impact of AML. Minimize entry of runoff into mines.	Difficult to regrade steep slopes. May destroy existing natural revegetation.	400 - 800

Cost range reflects differences such as site access, wall rock stability, opening size, contractor method and site to site variations.

Reclamation Recommendations - Adits

Based on all information gathered, recommended closure and reclamation options for the 10 identified open adits (see Figure 19 for locations) are in Table 11. Of these, only two (SCM 5 and SCM 11) have intermittent or continuous drainage. All other adits are dry. Recommendations for reclamation of the 22 collapsed adits are also in Table 11 and locations are on Exhibit 1. Locations of all reclaimed adits should be surveyed and tied to a permanent survey marker and included in the project Phase II report. The adit locations also should be recorded on surface ownership deeds.

TABLE 11. RECLAMATION AND CLOSURE RECOMMENDATIONS FOR ADITS IN THE SAND COULEE STUDY AREA

Site	Recommended Reclamation Option	Remarks
	OPEN ADITS	
A1	Wooden bulkhead	Partially full of water, poor access for equipment.
A2(SCM 5)	Wooden bulkhead with provision for drainage	Discharging. Poor access for equipment.
A3	Backfill with adjacent material, regrade and revegetate	Partially collapsed.
A4	Backfill with adjacent material, regrade and revegetate	
A5	Backfill with adjacent material, regrade, and revegetate	Will require access from landowner.
A6	No action	Has wooden doors, privately owned, currently used.
A7 (SCM 11)	Backfill with adjacent material, regrade, and revegetate.	Floor dry. Possible pneumatic backfill site for waste piles 19 and 20.
A8	Wooden bulkhead	Difficult access and too near town for blasting.
A9	Backfill with adjacent material, regrade, revegetate.	Reclaim in conjunction with waste pile 27.
A10	Backfill with adjacent material, regrade, revegetate.	Reclaim in conjunction with waste pile 27.

Table 11, continued

Site	Reclaimed Reclamation Option	Remarks
	COLLAPSED ADITS	
Collapsed adits associated with waste piles 13,14,15,21, 22,23,26, 27,29	Backfill with adjacent material, regrade, revegetate.	Reclamation recommended in conjunction with reclamation of waste dumps.
All other collapsed adits within study area	No Action	Collapsed dry adits pose little health, safety or environmental risk, and access is generally poor.

AIR SHAFTS

Plugging of the two air shafts could be accomplished by several methods. Both shafts above Kate's Coulee appear to be partially filled or caved and additional fill material could be dumped into the shafts. Constructed caps consisting of a poured concrete slab over a wooden bulkhead, pre-stressed concrete slabs, concrete bulkhead, or pre-formed concrete cone could be used to seal the open shafts. Both sites are accessible for equipment but one is on a side slope and only has good access from above. The following outlines reclamation options for plugging of the air shafts.

AIR SHAFT RECLAMATION ALTERNATIVES

Alternative	Advantages	Disadvantages	Approximate Cost
Wooden Bulkhead	Low cost; allows backfill and re-vegetation	Temporary solution	$1500 - 2600
Poured Concrete Bulkhead	Long-term; allows backfilled revegetation; low risk of failure; proven technology	Requires access for concrete truck	$1900 - 2700
Pre-Stress Concrete Slab	Quick Installation	Possible erosion under slab; Equipment difficulties with emplacement;	Uneconomical due to lack of pre-stress facilities
Pre-formed Concrete Cone	Proven technology; Long-term seal; allows backfill and revegetation.	Difficult installation; unknown availability of cones.	$2100 - 3100
Fill with Earth Material	Inexpensive and simple.	May settle or collapse and require further work.	800 - 1200

Reclamation Recommendations - Air Shafts

Recommendations for reclamation of the air shafts are in Table 12. Locations of the air shafts are shown on Figure 19. For both shafts, a concrete bulkhead is the preferred alternative. Filling with earth material is the second choice for reclamation.

TABLE 12. RECLAMATION RECOMMENDATIONS FOR AIR SHAFTS IN THE SAND COULEE STUDY AREA

Site	Reclamation Recommendation	Remarks
S1	Concrete bulkhead over temporary wooden form, cover with three feet soil, revegetate.	Concrete should be keyed into rock
S2	Concrete bulkhead over temporary wooden form, cover with three feet soil, revegetate.	May be able to back-fill over trash to provide base for concrete plug.

Locations of shafts should be surveyed from permanent marker and recorded with surface ownership deed.

ACID MINE DRAINAGE

There are six adits in the study area that have continous or intermittent drainage. Detailed evaluation of long-term solutions to these acid drainage problems is beyond the scope of this study. Hydraulic seals, mine drainage and AMD treatment were evaluated as potential solutions to the AMD problems in the Sand Coulee study area by Hydrometrics (1982). Hydraulic seals appear to have too great a risk of failure or, if successful in sealing one portal, of causing

discharge at other locations. Sand Coulee residents are very opposed to sealing of adits. Treatment of AMD is not considered feasible because of the high maintenance cost and the highly variable flow rates from the mines. Mine drainage utilizing vertical or horizontal wells may have some potential in the Sand Coulee area and is being investigated by the MBMG under contract to DSL.

In this investigation, the primary focus has been to evaluate control of acid drainage from adits SCM 6 and SCM 11, both of which have caused flooding and erosion problems on private property. Discharges SCM 2, SCM 3 and SCM 5 go directly to stream channels with essentially no impact on property. SCM 16 is intermittent and flows seep back into the ground within a short distance and have little impact. Drainage control would involve collection and conveyance to Sand Coulee. Discharge from both SCM 6 and SCM 11 varies in quantity and at SCM 6 a second adit periodically has small discharges. Collection of AMD in sumps or small lined ponds and conveyance to Sand Coulee by pipeline or open ditch is the most appropriate method of handling the drainage. To control seepage, any ditch sections should be lined.

Reclamation options for SCM 6 depend to some extent on the reclamation plan chosen for the large coal slack and cinder pile comprised of sites 15, 16 and 17 (Exhibit 1). A long narrow pond that would intercept the occasional flow from the adit north of SCM 6 and the flow at SCM 6 would collect the AMD. This pond should be lined with an acid-resistant membrane or with compacted clay to collect the drainage and

seepage. Collection pond design would include a control structure to direct drainage to the outflow ditch or pipeline and to divert overflow to an overflow spillway. A buried pipeline of corrosion-resistant PVC, would be adequate to convey the AMD down the steep hillside and then into an existing culvert under the highway. Use of a buried pipeline would require about 500 feet of pipe and would have a grade of about 37 percent in the steep hillside section. If ditches are used, two general routes are available. One ditch could cross pile 15 to the south for a distance of about 1100 feet at a grade of about 5 percent. A steeper ditch route could be installed to the north down through piles 16 and 17 for a distance of about 650 feet with sections of grade as steep as 20 percent. Both ditches would require drop structures and riprap. Freezing and clogging of the inlet control structure would be a concern with either ditches or pipelines. A small inlet structure and trash racks also would be needed. Periodic maintenance of the collection pond, and pipeline or ditches would be required. A berm and ditch diversion above Mary Surmi's residence would help control overflow and seepage of AMD and surface runoff which causes erosion.

Objectives of reclamation of discharge SCM 11 are to collect the AMD, transport flow across waste piles 19 and 20 and under Tesinsky's access road and discharge to Sand Coulee without the present erosion problem. A collection pond and ditch or pipe conveyance with an overflow ditch along the road is a potential solution to the existing problem of winter freezing. The existing shallow 4-inch PVC pipe reportedly freezes during most winters. Collection pond and ditch sections would

require periodic maintenance. A buried plastic pipe under the road and down the embankment to Sand Coulee would reduce or eliminate freezing problems. Another possible solution would be to install tile or plastic drain pipe to collect the AMD flow which discharges from waste pile 19. The drain pipe could be buried below the access road and discharge to Sand Coulee. A drain system should be supplemented by a backup system consisting of an unlined ditch along the edge of the road and a acid-resistant culvert beneath the road.

Any plans for drainage control of SCM 11 should be coordinated with Bill Tesinsky and with reclamation of waste piles 19 and 20 and the open adit.

Reclamation Recommendations

Recommended mitigation of AMD is directed at minimizing onsite damage to property but must be recognized as a temporary measure that does not reduce downstream and downgradient water quality impacts. Recommendations for reclamation of acid mine drainage problems are in Table 13 and AMD sites are shown on Figure 2 and Exhibit 1. No action is recommended at this time to try to seal adits or treat acid drainage in the Sand Coulee study area. Work underway by MBMG or possible future technology may provide cost effective solutions to control acid drainage from adits in this area. No such solutions are presently available for the sites examined as part of this study.

TABLE 13. RECLAMATION RECOMMENDATIONS FOR ACID MINE DRAINAGE

Site	Recommendations	Remarks
SCM 2	No Action	Periodic maintenance may be required for existing ditch.
SCM 3	Remove coal waste material between collapsed portal and stream to prevent further erosion; collect AMD in pipe for discharge to Sand Coulee (30 to 40 feet)	Would require periodic maintenace of pipe. Approximate pipe cost is $250 to $400. Should be coordinated with reclamation of water sites in this area.
SCM5	No Action	Install wooden bulkhead with provision for drainage as recommended for an open adit.
SCM 6	Construct collection sump and install buried PVC pipe to transport AMD to culvert under main road. Includes small intake structure.	Would require periodic maintenance, should be coordinated with reclamation of waste pile 15. Approximate cost is $3200 - $4600.
SCM 11	Construct collection sump and buried pipe to discharge under Tesinsky's road to Sand Coulee	Would require periodic maintenance and should be coordinated with reclamation of adit A7 and work piles 19 and 20. Approximate cost is $950 - $1450.
SCM 16	No Action	AMD has little impact on private property or surface water resources.

WASTE PILES

Reclamation alternatives for abandoned mine waste piles can be divided into onsite reclamation or removal of the wastes and offsite disposal. Revegetation techniques applicable to both onsite and offsite disposal are described.

Onsite reclamation options are:

1) erosion control with berms and ditches but otherwise leaving piles as they are;
2) amendment of soils and revegetation of the piles;
3) resloping, grading, covering with a suitable soil cover and revegetation of piles.

Offsite reclamation options are:

1) pneumatic backfill of waste material into open adits and revegetation of native ground beneath the dump sites;
2) removal of waste material to an existing or excavated disposal site, application of a soil cover and revegetation of both the transported waste and the former dump locations.

Erosion and Runoff Control

Both onsite and offsite disposal and revegetation will require drainage and erosion control. Construction of berms or ditches and small sediment traps at the base of the piles are recommended to control erosion. Sediment traps and ditches sized for five or ten year runoff events could be installed with a dozer, backhoe or grader at most sites

with little difficulty. The following are options for erosion control at waste piles.

DRAINAGE AND EROSION CONTROL RECLAMATION ALTERNATIVES

Site	Advantages	Disadvantages	Approximate Cost
Ditch	Directs flow to control erosion	Requires periodic maintenance	$1.30 - 3.00/ linear foot
Sediment traps (Approx. volume - 50 yds^3)	Reduces sediment load to stream	Requires periodic maintenance	$100 - 200/ each

Onsite Reclamation

Treatment of waste materials in-place with lime, organic mulch and fertilizer and revegetation is a potential reclamation alternative for waste piles in the Sand Coulee study area. Greenhouse trials conducted by Westech (1982) indicate neutralization and revegetation can be successful. Difficulty with determination of lime requirement and potential for reacidification make amendment and revegetation an option with a high risk of failure. Soil amendment would be most suitable for areas where a thin layer of coal slack or AMD runoff has affected private yards or agricultural land. Alkaline municipal sewage sludge from the City of Great Falls is a potential amendment that would supply both alkalinity and organic matter. Application of sewage sludge cake would be possible using standard farm equipment on some sites. Small sites, sites with poor access and sites on steep slopes (greater than

20 degrees) would have to be treated with small hand or garden-type equipment.

Grading, application of cover material and revegetation on site minimizes haulage costs and acreage to be reclaimed. Slopes should be graded to grades less than 20 degrees. Where grading requires increasing the size of the existing pile, all soils suitable for cover material should be stripped and stockpiled. Mine waste material should be limed. Lime incorporation should be as deep as practical; one and one-half to two feet could be achievable with large discs. Discing should be on contour and the surface left as rough as possible prior to application of cover material. Cover material, including topsoil and subsoil, should be applied in as thick a layer as is economically feasible. A minimum of four inches of soil cover is recommended for revegetating coal mine wastes in the Sand Coulee study area. A detailed discussion of cover soil application and liming requirements is provided in Appendix D. Cover materials and borrow areas can be revegetated using conventional farming equipment or where sites are steep or small, hand application or hydro-seeding may be appropriate. Revegetation involves fertilization, mulching and seeding to achieve satisfactory stand establishment.

Onsite regrading is most applicable to small dumps or where local slope and soil conditions required a minimum of disturbance of adjacent land. Techniques suitable for onsite reclamation of waste piles are summarized in Table 14.

TABLE 14. ONSITE WASTE PILE RECLAMATION ALTERNATIVES

	Advantage	Disadvantage	Approximate Cost
Lime Application (20 tons/acre incorporated to 1 foot)	Provides neutralization of acid waste material.	Application rate difficult to determine; may reacidify.	$1400 - 2200/ Acre
Cottrell Dust application (20 tons/acre incorporated to 1 foot)	Material cost less than lime.	Not locally available.	$ 550 - 850/ Acre
Fertilization	Necessary for adequate stand establishment.		$ 375 - 650/ Acre
Seeding			$ 300 - 500/ Acre
Mulching			$ 250 - 350/ Acre
Liquid Sewage Application	Provides organic matter, nutrients and lime.	Must haul liquid from Great Falls and have liquid applicator.	$8.00 -12.00/ ton solids (Liquid application may not be available)
Sewage Cake Application	Provides organic matter and nutrients.	Uncertain application method and may cause odor problem.	$6.00 - 9.00/ ton
Grading	Provides stable slope angles.	Disturbs larger area than presently disturbed.	Widely Variable

TABLE 14, continued

	Advantage	Disadvantage	Approximate Cost
Cover Soil (Assume 4" thickness)	Achieves good seed bed and promotes rapid stand establishment.	Need to locate, purchase, haul cover material and reclaim borrow area; may acidify if application is too thin.	$6.00 - 12.00/ yd^3
Revegetation (Includes fertilization, if needed, seeding and mulching).	Stabilizes regraded dump; reduces erosion; improves appearance.		$800 - 1300

Offsite Treatment

Pneumatic backfill of mine waste material into open dry adits has the advantage of permanent disposal and minimizes surface reclamation. This method is most applicable to sites with a large volume of wastes and adjacent or nearby open adits with adequate volume to receive the material. Waste pile 27 might be a suitable site but the volume of the open underground workings accessible from adits A9 and A10 is unknown. After the waste dumps are removed, the adit would be closed, covered with earth material and site graded and revegetated. Soils under former dump sites are typically acidified and often contain aluminum and iron precipitates from leachate passing through the dumps. Revegetation of these soils would involve lime incorporation, fertilization, seeding and probably mulching for adequate stand establishment.

Offsite burial of wastes would require emplacing a soil cover over the mine waste material and revegetation of former dump sites. This is a good option for many of the Sand Coulee study area sites. Offsite burial either requires an existing excavation or a topographically suitable burial site. Both options exist for mine waste materials in the Sand Coulee study area. Excavation of a burial site is an increased cost but provides cover material. Several large excavations exist adjacent to the study area that appear to be suitable for burial. Reclamation of haul roads, former dump sites and borrow areas results in a larger area requiring revegetation than for other reclamation alternatives.

Existing excavations potentially suitable for burial sites are just west of Tracy on land owned by Renee Lynch. The excavations were originally mined for clay used in brick manufacture but have not been disturbed for about 30 years (R. Lynch, pers. comm., 1983). The volume of the pits is not accurately known but is estimated, based on area and average depth, to be about 100,000 yards^3 or more. The pit bottoms are covered with sandstone rubble. One of the three pits has a small spring at the point of lowest excavation; this pit would have to be backfilled to avoid placement of acid-producing material at or near the groundwater table. Access for scraper or truck haulage to the clay pit sites is good although some access road may have to be built across a portion of a grain field.

Potential alternatives for offsite disposal of waste piles and reclamation are in Table 15.

TABLE 15. OFFSITE WASTE PILE RECLAMATION ALTERNATIVES

	Advantage	Disadvantage	Approximate Cost
Pneumatic backfill	Permanent disposal and fills openings.	Needs nearby fill source and special equipment.	$8.00 - 20.00/ cubic yard
Clean, reslope and regrade dump site	Improves site for revegetation.	May require more area	$0.50 - 1.00/ cubic yard
Revegetate dump site (includes lime, fertilizer, seed bed preparation, seeding and mulching)	Improve appearance, reduce erosion.		$1000 - 2000/ Acre Depends on lime needs.
Small pile clean-up with front-end loader.	Fast, simple and permanent.	Some sites are inaccessible.	$1.00 - 3.00/ $yard^3$
Load and haul (Assumes average 1½ mile round-trip haul)	Simple and permanent.	Requires disposal area.	$2.00 - 5.00/ $yard^3$
Scrapper haul (Assumes average 1½ mile round-trip haul)	Simple and permanent.	Requires disposal area.	$1.50 - 3.50/ $yard^3$
Disposal site excavation	Central area for disposal.	Requires disposal area .	$2.00 - 4.00/ $yard^3$
Cover soil and application (4 inch thickness)	Improve growing conditions.	Requires borrow site reclamation.	$6.00 - 12.00/ $yard^3$
Grade, fertilize and revegetate cover material	Improve appearance, reduce erosion.		$900 - 1400/ Acre
Grade, fertilize and revegetate former dump site (assumes suitable soil is present)	Improve appearance, reduce erosion.		$850 - 1350/ Acre

Reclamation Recommendations - Waste Piles

Reclamation recommendations for waste piles are in Table 16 and site locations are shown on Exhibit 1. Reclamation recommendations are made assuming the abandoned clay pits near Tracy will be available for disposal of mine waste material. If a suitable disposal site is not available, a number of the sites recommended for removal and burial would be best treated by onsite sloping, regrading and covering with soil. Priority should be given to sites causing problems to private property and sites immediately adjacent to the Sand Coulee stream channel. These include sites 5 (and several small piles nearby), 12, 15, 16, 20, 24, 25, 26 and 29.

Several sites can logically be reclaimed as a unit and are grouped in the reclamation recommendations in Table 16. The groupings are based on nearness of the sites or similarity of reclamation techniques. A number of individual sites or grouping of sites also could be combined in a single construction contract.

TABLE 16. RECLAMATION RECOMMENDATIONS - WASTE PILES

Waste Dump Sites	Recommended Reclamation	Remarks	Material Volume (yds^3)	Approximate Cost of Recommended Reclamation
1, 2, 4, 5, 6 and associated small waste sites.	Combination of removal to nearby existing excavations or depressions and onsite cover and revegetate.	Existing subsidence pits and abandoned foundation excavations could be used for disposal. Top soil should be salvaged from subsidence depressions.	600	$ 1,900 - 2,700
3	No Action	Landowner does not want this site reclaimed.	-	
7	No Action	Out of study area.	-	
8	No Action	Landowner does not want this site reclaimed.	-	
9	Removal, burial and revegetation.	Volume estimate may be inaccurate	5,400	11,900 - 22,900
10, 11	No Action	Sites have very difficult access for equipment.	-	
12	Onsite cover material application and revegetation.	Site may be suitable for municipal use.	280	3,900 - 4,400
13, 14, 15, 16, 17	Removal, burial and revegetation.	Largest volume of mine wastes of this logical reclamation unit in study area and steep slopes make this the most difficult and expensive of the recommended AML reclamation options.	42,000	97,000 -147,000
18	Removal, burial and revegetation.	This dump is actively used by Hobart Feller and reclamation and future use should be coordinated with him.	30	200 - 350
19, 20	Onsite regrading, cover material application, revegetation, riprap of slope adjacent to stream.	Much of the material at site 20 is used for road fill. Reclamation should be coordinated with Tesinskys.	300	1,400 - 1,800
21, 22, 23	Removal, burial and revegetation.		3,400	6,000 - 8,000
24, 25	Onsite regrading, liming, cover soil application, revegetation and drainage and erosion control.		150	3,300 - 4,500
26	Removal, burial and revegetation	Need soil amendment of small portion of field below dump.	2,900	7,800 - 9,800
27, 28, 29, 30	Removal, burial and revegetation; disposal of wooden structure.	Removal of slack coal at site 27 may require interception and rerouting of SCM 16. Small area of field below site 29 needs liming and soil amendment.	5,500	9,500 - 12,000
Small waste piles above Reeves, Wiel and Korin residences	Onsite regrading, liming, cover soil application, revegetation and drainage and erosion control.	Several small waste piles which cause sedimentation problems (< 1/4 acre).	<50	1,200 - 1,600

SUBSIDENCE

Land subsidence occurs at several locations in the study area and, although it is not a significant safety hazard, the subsided areas may allow increased percolation of precipitation and surface runoff to underground mine workings. Reclamation alternatives for subsidence primarily involve filling existing depressions. Fill material could be either local soils or mine wastes. Salvage of soil from subsidence depressions prior to backfilling and reuse as a cover material for revegetation would be the most economical option for revegetation. Approximately 40 subsidence depressions have been identified and are shown on Exhibit 1. Subsidence depressions in the Sand Coulee study area have an estimated average volume of 15 to 30 yards^3 and cover an average area of about 100 to 250 ft^2. Reclamation alternatives for subsidence are as follows.

SUBSIDENCE RECLAMATION ALTERNATIVES

Alternative	Advantage	Disadvantage	Approximate Cost
Backfill with imported borrow material and revegetate.	Reduces percolation to mine workings	Requires borrow material.	$75 - 150/ site
Backfill with mine waste material, cover with existing soil and revegetate	Provides disposal site for mine waste and reduces percolation to mine workings.	May reacidity if insufficient soil cover is available.	$50 - 125/ site

Reclamation Recommendations

The recommended alternative for subsidence depressions in the study area is backfill with mine waste material, cover with existing soil and revegetate. Total cost for reclamation of the estimated 40 subsidence pits in the study area is $2,000 to $5,000.

STREAM CHANNEL

Degradation of the Sand Coulee channel through the communities of Sand Coulee and Tracy by acid drainage and AML-related sedimentation creates a strong negative visual impact from all major roads in the area. Stream channel degradation was a concern commonly expressed by local residents during interviews and cleaning out the stream channel is probably the AML reclamation project of greatest local interest. Flooding of Sand Coulee within the study area is poorly documented but appears to have caused little or no significant property damage in the last ten years. Undersized culverts do, however, create a potential for flooding over roads and onto private property for runoff events of 10 to 25 year or greater recurrence interval. Poorly planned drainage control along roads and in residential areas cause localized erosion and flooding problems for smaller snowmelt and rainfall runoff events.

Reclamation alternatives for the Sand Coulee channel include removal of debris, bank revegetation, culvert replacement, channel realignment, selected riprap emplacement and channel reconstruction. In addition to the Sand Coulee channel, several small drainage control projects that involve runoff from ALM affected tributary drainages are included in this review of reclamation options.

Several of the reclamation options for the Sand Coulee channel and other AML-related problems would require periodic maintenance. It is possible that some of the drainage control, culvert or bridge work

could be coordinated with Cascade County to insure continued long-term maintenance of AML-funded projects.

Culvert Replacement

Upgrading undersized culverts to pass a 25 or 50 year runoff event would reduce the occurrence of periodic flooding. Planning for 25 year return period flooding is common on secondary roads. Acid stream conditions make design and construction for longer return period flooding difficult to justify. Culvert locations 1, 2, 3, 5 and 8 (Figure 13) could be upgraded with little difficulty. Culvert sites 6 and 7 under the highway at the Tracy intersection have limited height available and could, perhaps, be better served by a box culvert or bridge. Culvert replacement at site 8 under the railroad tracks at the north end of the study area would need to be coordinated with Burlington Northern. Bank erosion appears to be a major contributor to the sediment load in Sand Coulee and could be largely controlled by riprap. Riprap, cover soil and revegetation as shown in Figure 20 could be used to improve the appearance and stability of the channel. Riprap along the long straight reaches of Sand Coulee would provide a benefit during very high flows but would be very costly. First priority for riprapping should be in existing areas of accelerated erosion where bank materials are composed of coal mine wastes and where banks are affected by construction disturbances. All culvert replacements must be coordinated with Cascade County and any stream work must be authorized under the Streambed Preservation Act (Senate Bill 310).

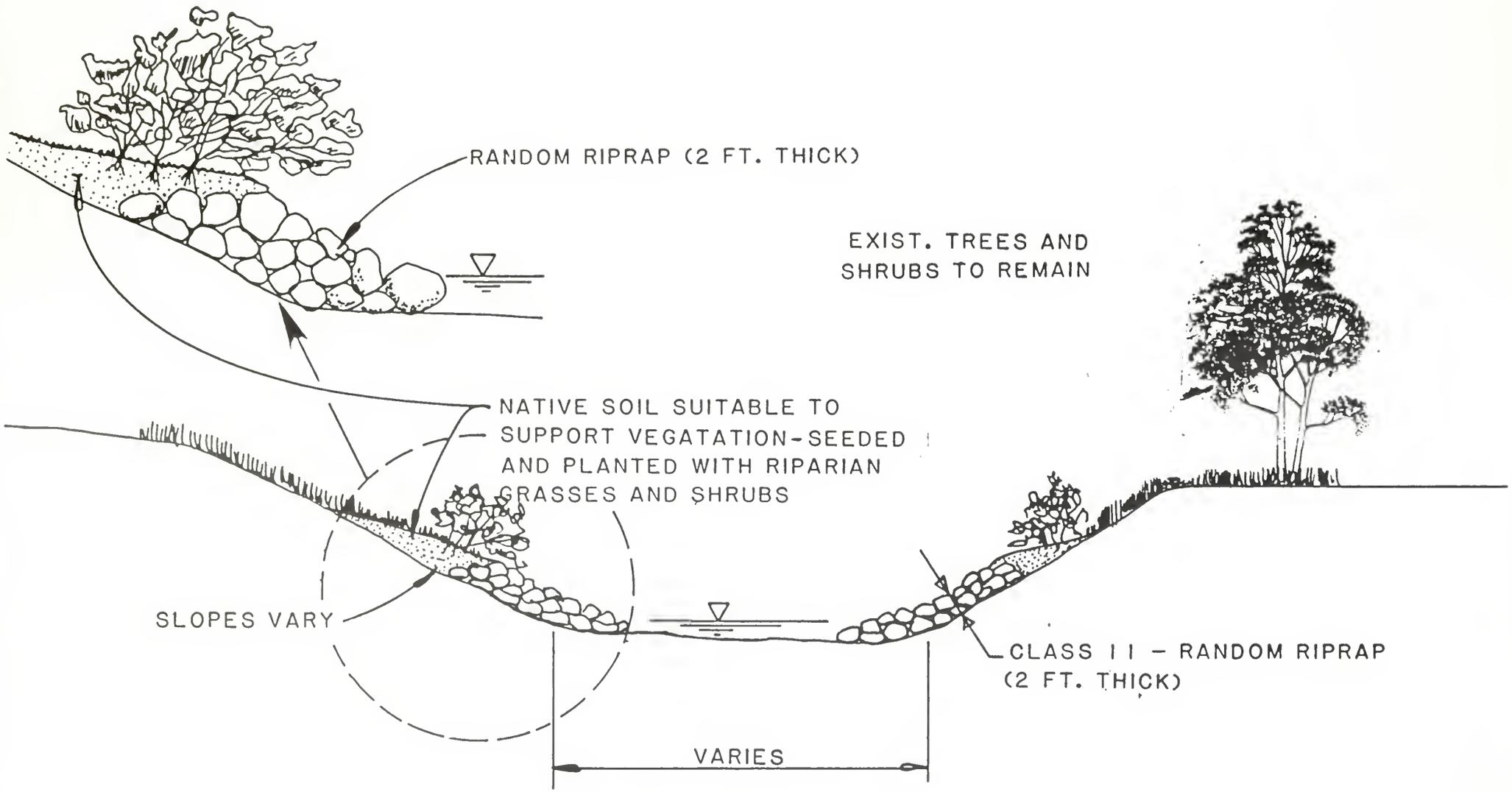


FIGURE 20

RECLAMATION OF SAND COULEE RIPARIAN ENVIRONMENT

Channel Reconstruction

Channel realignment and reconstruction could be utilized to increase channel meandering, remove nick points and smooth-out the channel profile and to enlarge the channel capacity. Adding meanders would decrease channel gradient and flow velocity. Because of the already low baseflow velocities and loss of flow below the community of Sand Coulee, any increase in channel length would increase seepage into underlying alluvium. Much of the existing bank material consists of relatively unstable mine wastes. Any channel alterations or realignment involving easily erodible mine slack material would require extensive riprap and revegetation efforts.

Below the MBMG wier, between Sand Coulee and Tracy, the long straight channel reach could be realigned away from the highway. The existing right-of-way appears to be of adequate width and a parallel channelway already exists. Diversion of Sand Coulee into this easterly channel would visually screen this reach from the road. The existing channel could be retained as a floodway and, with minor improvements to the easterly channelway, the flood capacity could be significantly increased. If this realignment option is chosen, it should be coordinated with plans for replacement of culverts at sites 6 and 7 near Tracy.

Reclamation alternatives for the Sand Coulee channel and approximate reclamation costs are listed in Table 17.

TABLE 17. STREAM CHANNEL RECLAMATION ALTERNATIVES

Alternatives	Advantage	Disadvantage	Approximate Cost
Clean Sand Coulee bed and banks (Trash & Debris)	Immediate, low cost improvement in channel appearance, decreases risk of flooding from debris clogging culverts.	Temporary solution	$0.75 - 2.00/ foot
Culvert Replacement; Increase size of culverts 1,2,3, 5 and 8 to pass 25 year event	Provides safe passage for 25 year flow event.	Temporary erosion and readjustment of stream channel.	$120 - 150/ foot or about $5400 for a 40 foot culvert.
Replace culverts 6 and 7 with bridges	Provides safe passage for 50 year flow event.		$15,000/each
Riprap selected banks, road crossings and eroding areas (Estimate 1500 ft, and 500 yds^3 of riprap.	Reduce bank erosion, may enhance bank revegetation efforts.	Requires riprap source.	$12,500 - 17,500
Rehabilitate channel below MBMG weir away from road (includes 2200 feet of channel preparation; a diversion structure) and removal and reclamation of removed material.	Improves visual appearance, reduces channel and bank erosion risk.	Requires periodic maintenance of channel and diversion structure.	$11,500 - 17,000
Channel reconstruction (includes adding meanders, grading channel to smooth longitudinal profile, riprap). Reach downstream of MBMB weir considered.	Return stream channel to more natural looking configuration, should increase channel capacity	Difficult to accomplish through short sections because of upstream and downstream grade control. AMD precipitates would eventually degrade reconstructed channel, little room to reroute channel.	More than $30,000 (Depends on design)

Table 17, Continued

Alternative	Advantage	Disadvantage	Estimated Cost
Bank revegetation for erosion control and visual screening (includes topsoil in selected areas and riparian grass, shrubs and tree planting, fertilization, liming and mulch).	Improves visual appearance, reduces channel and bank erosion risk.	May be difficulties with stand establishment in acid materials, requires maintenance including, perhaps, irrigation for first year or two.	$3.00 - 8.00/ linear foot (Depends on revegetation plan).

Reclamation Recommendations - Stream Channels

Recommended reclamation for the Sand Coulee channel incorporates a number of the options listed above. First priority would be to upgrade the culverts. Replacement of culverts 6 and 7 with bridges or with box culverts is recommended but should be reviewed with the Department of Highways prior to making a final decision. Estimated cost for culvert and bridge replacement is $58,000 to $75,000 depending on final design criteria and requirements of the Department of Highways. Cleaning and revegetation of the stream channel from the Mining Coulee confluence to culvert 5 below Sand Coulee is the second recommended reclamation priority. Estimated cost for cleaning and revegetating this approximately 6500 feet of stream channel is $36,000 to $49,000. As a third order of priority, it is recommended that selected stream sections be riprapped (estimate 1500 feet), the channel be rerouted below the MBMG weir to an old channelway away from the highway and Kate's Coulee be cleaned and riprapped. Cost of these three projects is estimated to range from $25,900 to $37,300. Channel reconstruction below the MBMG weir is not recommended because of high cost and small benefits. Total estimated cost of all recommended channel rehabilitation ranges from $112,000 to $161,000. Recommended channel reclamation options are summarized in Table 18.

TABLE 18. RECLAMATION RECOMMENDATIONS FOR STREAM CHANNELS

Site	Recommendation	Remarks
Sand Coulee Channel	Upgrade culverts to pass 25-year, storm runoff and install bridges or box culverts at culvert locations 6 and 7.	Requires coordination with County, State Highway Department and Burlington Northern. Estimated cost is $58,000 to $78,000.
Sand Coulee Channel from Mining Coulee to Culvert 5	Clean channel and revegetate riparian zone.	Should coordinate community involvement. Estimated cost is $36,000 - $49,000.
Sand Coulee selected sections from Mining Coulee to Tracy	Riprap for erosion control.	Estimate 1500 feet of riprap. Estimated cost is $12,500 - $17,500.
Sand Coulee between MBMG weir	Reroute channel away from highway. Include small diversion structure.	Estimated cost is $12,500 - $17,500.
Kate's Coulee below SCM 5	Rehabilitate channel, haul material to burial site, revegetate north bank.	Estimated cost is $1900 - $2800.

WELLS

Several wells drilled in the Sand Coulee study area apparently have been affected by acid mine water. One abandoned well drilled by Tesinskys (Table 9) apparently encountered acid and metal-contaminated water in alluvium. Two other wells, apparently completed in the Morrison Formation, show some indications of possible contamination from acid mine water. These wells belong to Lyman and Lynch and are both located west of Tracy. The Lynch well has been abandoned for a number of years.

Reclamation alternatives include development of alternative water supplies and continued monitoring to determine health hazards and changes in water quality. Tesinskys have already connected to the Sand Coulee Water Users System and the Lyman well is currently used for domestic and stock supply. Replacement of the Lyman well would probably require completion in the upper portion of the Madison limestone. Assuming the Madison is not contaminated at this location, replacement of the existing well to supply 15 to 20 gpm would cost an estimated $6,000 to 8,000. Baseline data on groundwater quality does not exist and the existance or extent of pollution of the Lyman and Lynch wells are difficult to evaluate. The Department should consider development of a standard policy on replacement of abandoned wells before proceeding with any replacement at Sand Coulee. If replacement is offered to one or more affected parties, additional claims of groundwater contamination may occur. The cost of providing or refuting

any claim of groundwater pollution could be high and the overall responsiblity of the state must be considered.

Reclamation Recommendations

Reclamation alternatives recommended for wells in the Sand Coulee study area are in Table 19.

TABLE 19. RECLAMATION RECOMMENDATIONS - WELLS

Site	Recommendations	Remarks
Tesinsky well (19N04E13CBAD)	No Action	Abandoned
Lynch Well (19N04E12DCCD)	No Action	Not presently used
Lyman Well (19N04E12DABA)	Periodic Monitoring to detect changes in water quality	Should this well prove to be contaminated, alternative sources of household water should be investigated.

APPENDIX A

LIST OF ABBREVIATIONS

ABBREVIATIONS

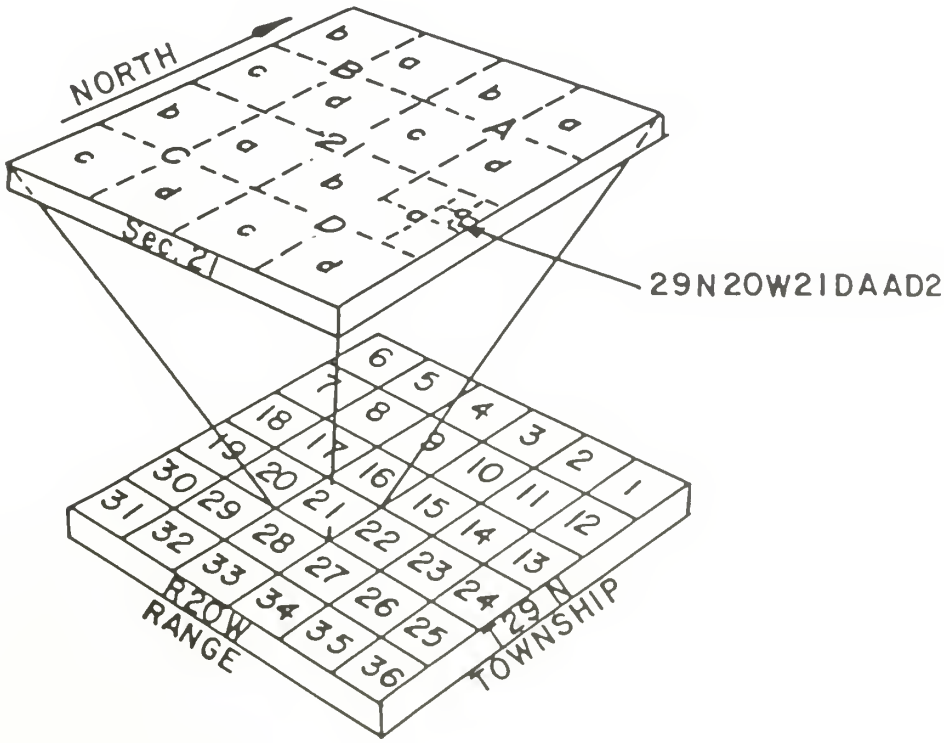
AMD	Acid Mine Drainage
AML	Abandoned Mine Land
cfs	cubic feet per second
DSL	Department of State Lands
fps	feet per second
gpm	gallons per minute
MBMG	Montana Bureau of Mining and Geology
PVC	poly vinyl chloride
SCS	Soil Conservation Service
USGS	United States Geological Survey

APPENDIX B

GEOGRAPHICAL LOCATION OF FEATURES

SYSTEM FOR GEOGRAPHICAL LOCATION OF FEATURES

Geographic features such as sampling sites, wells and springs are assigned a location number based on the system of land subdivision used by the U. S. Bureau of Land Management. The number consists of 10 to 16 characters and describes the location by township, range, section and position within the section. The figure below illustrates this numbering method. The first three or four characters of the number give the township, the next three or four the range. The next two numbers give the section number within the township and the next letters describe the location within the quarter section (160-acre tract) and quarter-quarter section (40-acre tract). If the location is known to sufficient accuracy then one or two additional letters can be used to describe the quarter-quarter-quarter-quarter section (2 1/2-acre tract). These subdivisions of the 640-acre section are designated as A, B, C and D in a counterclockwise direction beginning in the northeast quadrant. If there is more than one feature in a tract, consecutive digits beginning with the number 1 are added to the number. For example, if a sampling site was in Section 21, Township 29 North, Range 20 West, it would be numbered 29N20W21DAAD2. The letters DAAD indicate the well is in the southeast 1/4 of the northeast 1/4 of the northeast 1/4 of the southeast 1/4 and the number 1 following the letters DAAD indicates there is more than one site location in this 2 1/2-acre tract. If geographic features are located to the nearest 40 acre or 10 acre tract, the numbering methodology is the same except the last one or two letters are absent.



APPENDIX C

LOCAL RESIDENT INTERVIEWS

APPENDIX C

June 3, 1982 - Albert Korin's home is located about 2 blocks southeast of the Sand Coulee Post Office. Mr. Korin reported having water in his basement. There is a plugged portal that shows signs of recent seepage located about 100 yards horizontally and 40-50 feet vertically above Mr. Korin's home. It appears that heavy rains may have caused the mine to act as a collector and conduit of moisture, directing water to the site of Mr. Korin's home. (Interview by Tom Wing and Lisa Larsen)

March 31, 1983 - Gordon Mindt's home is located north of Tracy, next to culverts 8A and 8B. Mindt's built a concrete wall along the stream channel and lined other parts of the channel with tires to "prevent flooding and keep the water moving faster". They have had no trouble in the ten years they have lived there except with wood and garbage clogging up the culverts. Once a bedspring got trapped in front of the culverts and flooded their yard and house.

April 25, 1983 - George Kavulla's home is located on the northeast edge of Sand Coulee, about 500 feet of waste pile number 25. Mr. Kavulla reports having problems with flooding in his back yard. Runoff from the drainage above Mr. Kavulla's

home has overflowed the channel and run into his yard. There is coal slack located near Mr. Kavulla's yard that has apparently been deposite by runoff.

June 2, 1983 - Theodore Mrochen's home is located on the northeast edge of Sand Culee, about 300 feet west of waste pile number 26. Mrs. Mrochen reported that they have some runoff problems in a six acre pasture that is located immediately southwest of their home. The drainage from the area around piles 24 and 25 passes through the pasture. The channel, as it passes through the pasture, is undefined and a wide area is covered with coal waste. There is about one half to one acre that is affected and currently is barren. Mrs. Mrochen said that every time the coulee runs, coal slack is deposited in their pasture.

June 2, 1983 - Vicky Joe Reeves' home is located about three blocks southeast of the Sand Coulee Post Office. Ms. Reeves reported that she has problems with spring runoff washing out her gravel driveway. There is a small waste pile and a collapsed adit located up a drainage about 200 feet from Ms. Reeves' home. These mining disturbances have caused coal slack and iron precipitates to be deposited on the driveway by runoff.

June 2, 1983 - The Richard Wiel's home is located about two and one half blocks southeast of the Sand Coulee Post Office. Mrs. Wiel reported that runoff has washed out their driveway. The runoff is often rusty colored and carries coal slack. The Wiel's two year old daughter got into the runoff water and was reported to be sick for a few days.

June 2, 1983 - Mary Ann Brown's home is located at the mouth of Kate's Coulee, about 150 feet west of culvert number 4. It was reported that the yard was flooded after the heavy snow in May 1983. The channel immediately above Ms. Brown's home is wide and flat and the increased flow from runoff caused the channel to overflow directing water into her yard.

June 2, 1983 - Hobert Feller's home is located about 400 feet southwest of waste pile number 18. Mr. Feller reported that his front yard gets flooded when Sand Coulee is running at very high flow. A portion of Feller's yard is in a low area that contains flood waters for a couple of days after high flows.

June 2, 1983 - A. G. Freeman's home is located about 750 feet downstream, from culvert number 3. Mrs. Freeman reported that they have not had any problems with

surface water flooding, but the basement of their home gets water in it when the creek is high.

June 2, 1983 - Howard Challinor's home is located about 200 feet south of waste pile number 18. It was reported that every spring the basement gets flooded from groundwater seeping in.

June 2, 1983 - Philip Parker's home is located about 150 feet southeast of waste pile 18. Mr. Parker reported that their front yard has been flooded occasionally by above normal discharges from SCM 6 and also when the creek is high enough to flow out of the channel. There has been coal slack deposited on the downstream portions of Mr. Parker's yard.

June 2, 1983 - Mrs. Pete Romanchuk's home is located about 400 feet south of waste pile 18. Mrs. Romanchuk's basement is continually flooded by groundwater flowing in from the direction of SCM 6 and from the stream. The flooding requires the basement to be pumped 24 hours a day. Mrs. Romanchuk currently has two pumps that run about two minutes out of every ten. She reported that the pumps need to be replaced every 1½ to 2 years because of the corrosive action of the water. The basement floor has the same rusty color as the stream channel.

June 2, 1983 - The E-Z Bar is located on the west side of Tracy near culverts 6A, 6B, 7A and 7B. The owner of the bar reported that the last flood that ran over the culverts was in 1954 after a cloudburst.

June 23, 1983 - Mary Surmi's home is located about 300 feet northwest of SCM 6. Waste piles 15 and 16 surround Mrs. Surmi's home on three sides. In the past, runoff and excess discharge from SCM 6 has been directed toward the house. Mrs. Surmi reported that she has had problems with her basement flooding and with coal slack being deposited in her yard.

June 23, 1983 - Bill Tesinsky's home is located about 100 feet southwest of SCM 11. An open adit is located adjacent to SCM 11. The Tesinsky's driveway was partially constructed using coal slack from piles 19 and 20 as fill. The discharge from SCM 11 drains through a plastic pipe that is buried just below the driveway surface. Mrs. Tesinsky reported that every winter the drain pipe freezes and causes the discharge to run across the driveway. This causes erosion of the road surface that requires mainenance on the driveway each spring.

Mrs. Tesinsky reported that when they build their home about four years ago, they had a well drilled for their water supply. The groundwater that the well was completed in was too contaminated to use. The Tesinsky's abandoned the well and are using water from the town system.

June 23, 1983 - Renee Lynch's home is located about one quarter of a mile northeast of the town of Sand Coulee. Mrs. Lynch reported that she hasn't had problems with flooding at her home since the county road was worked on. She reported several areas of agricultural land that have been affected by slack piles and runoff.

June 23, 1983 - Charles Frantzich's home is located in Walker Coulee about three quarters of a mile northwest of the town of Sand Coulee. Mr. Frantzich is the previous owner of agricultural land along the northwest side of Sand Coulee. Mr. Frantzich reported that, while he owned the property, he had not had any problems associated with mining disturbances. The present landowner is the Cascade Hutterite Colony.

July 1, 1983 - George Mittal is the manager of the Sand Coulee Water Users water system. Mr. Mittal reported that there are only two private wells in the town of Sand Coulee. One well is owned by George Kavulla and the other is owned by Theodore Mrochen. Both of these wells are over 285 feet deep. Other wells have been drilled in the area but have had to be abandoned because of groundwater contamination. Mr. Mittal also reported that a well was once drilled in the vicinity of the post office. This well was drilled to 90-100 feet and was abandoned shortly after completion due to contaminated water.

APPENDIX D

COVERSOIL AND AMENDMENT RECOMMENDATIONS FOR COAL WASTE DUMPS AT THE SAND COULEE PROJECT AREA

COVERSOIL AND AMENDMENT RECOMMENDATIONS FOR COAL WASTE DUMPS AT THE SAND COULEE PROJECT AREA

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EXECUTIVE SUMMARY

The primary problem with mine waste materials at the Sand Coulee site is the very low pH (2-5). It is neither cost feasible nor physically available to apply many feet of good quality topsoil over all mine waste in order to assure successful plant production. There is no scientific evidence to indicate a few inches (e.g. 4 inches) of topsoil will suffice. Existing field tests at the project site with 4 inches of topsoil look promising but genuine concerns are present that the topsoil may acidify in the long-term resulting in revegetation failure. The mine waste has a very low pH. If it is also very acid producing (from sulfide oxidation) it is probable that much or all of the 4 inches of topsoil will acidify. At present the acid producing potential of the mine waste has not been determined.

Irregardless, a few inches of topsoil will not provide an adequate depth for rooting and plant productivity will be far short of optimum. The pH of the mine waste material must be reduced with lime (either CaO, $CaCO_3$ or $Ca(OH)_2$) deep as possible prior to topsoil application. Existing tillage equipment probably can't incorporate lime deeper than 1 or 2 feet into the waste. The required lime rate to neutralize the mine waste for the life of the site cannot be determined from the existing data base. Samples must be analyzed for acid-base account in order to arrive at a lime rate for field application.

Surficial liming is not expected to influence the pH of acid mine drainage in the Sand Coulee project area.

BACKGROUND

At the Sand Coulee site both cinder dumps (sites 3A, 2C, 3B, 8, 13B, 22; Westech 1983) and slag piles (sites 1C, 13B; Westech

1983), present at approximately 30 sites, require amelioration before they will support revegetation efforts. The very low pH of cinder-slag waste along with generally high salinity, Mn, Cu and B levels of cinder waste results in these materials being unsuitable for plant establishment.

Natural soil areas beneath and downslope from waste dumps have been contaminated by leaching/runoff processes resulting in acidification of the top 1 to 5 feet of the soil profile (sites 7A, 10, 11, 12, 1B, 2B, 4A, 5A, 6, 9, 13, 23, 1D, 2A, 15, 17, 19, 24; Westech 1983). In these soils the DTPA extractable Al was often present at elevated levels, but soluble salts and trace metals were determined to be at low levels.

Some natural soils in, or near, the project area are not contaminated and contain physicochemically suitable materials as deep as 7 feet (14A; Westech 1983). More often non-contaminated soils very near areas requiring reclamation have shallow (.5-1.5 ft) profiles of suitable materials (sites 1A, 1D, 16, 18, 21; Westech 1983). The potential exists to borrow A and B soil horizon material from non-contaminated sites to apply as coversoil on mine wastes. Certainly productive range or cropland would not be used as a borrow area but road cuts, deep alluvium deposits, and land leveling operations, for example, may make available some coversoil for reclamation.

The Montana Department of State Lands recently led a reclamation effort at the Sand Coulee site where mine waste material was covered with 4 inches of topsoil and seeded. A nominal lime application (approximately 1 T/A) was applied to the waste prior to topsoil application. To date general field observations indicate the site is doing very well although there are concerns that in the long-term acidification of the topsoil may cause revegetation failure (personal communication, R.L. Junteunen, 1983). At another mine reclamation site (Heal) the Department of State Lands had topsoil applied to mine waste material. Here the topsoil application had variable thickness (1 to 4 inches) and observations indicate reacidification and revegetation failure was apparent where the topsoil was present in only a thin application.

OPTIMUM COVERSOIL THICKNESS ON ACID MINESOILS

In the western United States there has been only one published study that addressed the question of how much coversoil is required over acid producing spoils. At two coal mine sites in Wyoming, Barth and Martin (1982) constructed a topsoil wedge (0-5 ft) over acid spoils (pH 3.6 to 4.3). As soil depth increased, perennial grass yield increased in a linear manner and maximum yields occurred at topsoil depths greater than 5 feet (the maximum wedge depth). Root penetration into acid spoil was minimal and never exceeded 8 inches. Plant roots always pene-

trated the maximum depth of the topsoil provided. Wyatt et al. (1980) also determined that Montana grass-shrub plant communities will quickly (1 to 3 years) root to the 6 foot depth in minesoils if toxic zones are absent in the soil profile.

It is apparent that at abandoned mined sites such as that at Sand Coulee, 5 feet or more of coversoil is not available for reclamation. Topsoil applications of only several inches over acid mine waste will result in only a fraction of the plant productivity that would be obtained with several feet of topsoil. Therefore when several inches of topsoil are available for reclamation the acid mine waste should be physicochemically amended deep as possible in order to provide a rooting medium more deep then a few inches of topsoil.

For the most part, three soil series are present in the Sand Coulee project area delineated by Hydrometrics (Figure 1). The A and B horizon from these soils are physicochemically suitable for use as topsoil on mine waste (Table 1). Only the Fergus silty clay loam soil, valley bottom alluvium, contains a thick (30 inches or more) A and B horizon, while the Yawdim-Rock complex and Bitton-Roy (present on valley slopes) soil series have salvagable soil materials less than 12 inches thick. It is probable that isolated sites in the valley alluvium will be many feet thick (3 to 7 ft) and these locations would be the best borrow pits for topsoil. In order to minimize the area of new land disturbances, topsoil salvaging may need to be largely confined to valley bottom alluvium.

Upland areas adjacent to the project area are generally in crop production and have physicochemically suitable A and B horizon material for use on mine waste. These soils (e.g. map code 204, 32, 108) generally have less than 20 inches of A and B horizon material.

More often than not, cost feasible topsoil will not be available for reclamation of abandoned mine waste and such sites will need to be physicochemically amended before plant establishment is attempted.

AMENDING SAND COULEE ACID MINE WASTE WITH LIME

The pH of most mine waste materials at the Sand Coulee site range between 2 and 5. Without question plant productivity will increase linearly with increases in waste pH. Westech (1983) produced some greenhouse test data that demonstrated this principle with mine waste from the Sand Coulee site. Results of that work shall be discussed since an interpretation error is present.

Westech consultants (Choriki and Sandoval) demonstrated with pot growth tests in the greenhouse how 10 or 20 T/A lime could

Figure 1. Soil map of the Sand Coulee project area

Table 1. Characteristics of some soil series for topsoil salvage in the Sand Coulee project area (data derived from Cascade County soil survey).

Map Code	Soil Series	Slope Range (%)	A and B Horizon Thickness (inches)	Physicochemical Limitations
80	Fergus silty clay loam	0-2	>30	None
232	Yawdim-Rock complex	25-70	3	None
28	Bitton-Roy	10-65	7-12	None
204	Timberg-Castner	2-10	<20	None
32	Borky-Sinnigam	2-15	14	None
108	Ipano-Ticell loams	4-10	<20	None

increase plant production 1 to 5 times in Sand Coulee mine waste. These liming results were utilized when recommendations were written regarding reclamation of cinder and slag piles as well as contaminated natural soils. The 10 and 20 T/A rates were not based on any soil analysis; these rates were simply selected. In the short term of a greenhouse test the process of reacidification, due to oxidation of sulfide minerals and organic sulfur, does not have time to proceed and go to completion. In the greenhouse and in the field 10 or 20 T/A lime would increase pH significantly resulting in immediate revegetation success, but reacidification in the field is possible and was not accounted for in the Westech work.

There does not appear to be a data base developed for the Sand Coulee mine waste material from which lime recommendations can be recommended. The goal must be neutralization for the life of the minesoil. To accomplish this the total acid production possible from the waste material must be known. Commonly used agricultural lime tests are not appropriate for mined land reclamation problems. Most agricultural tests evaluate the readily exchangeable H^+ (acidity) or soluble acidity (pH) by several methods (e.g., Woodruff, 1948; Peech, 1965). No consideration is given to the total potential acidity that can be generated over the long term by relatively insoluble minerals such as pyrite. For this reason agricultural soils generally reacidify a few years after a lime application which only neutralized the reaily available acidity.

In 1974 Smith et al. recognized the limitations of agricultural lime tests in their West Virginia acid mined lands and developed a new approach. Laboratory tests indicated all overburden sulfur was present as pyrite (FeS_2) at eastern mine sites. Therefore a total-S analysis with a LECO furnace provided the means to analyze the total acid producing potential of mine materials. From the stoichiometry of the reaction of the oxidation of FeS_2 it can be calculated that a 6-inch acre slice (1,000 tons of soil) containing 1.0% sulfur as pyrite will yield upon complete oxidation a quantity of H_2SO_4 that will require 31.25 tons of $CaCO_3$ (lime) for total neutralization.

Sobek et al. (1978) realized that just as there was reserve acid production from pyrite there were reserve bases present that could neutralize part of the acid. These neutralizing bases generally present as carbonates (e.g., $CaCO_3$) and cations can be constructed where the material is only acid producing if acid production from pyrite is greater than the neutralizing potential.

The acid-base account method is the state-of-art for determining a lime recommendation for an acid producing minesoil. This analysis is available from service laboratories in Montana and should be performed on samples from the Sand Coulee project area.

Although the acid-base account method is the state-of-art it has serious accuracy problems. The analytical technique is difficult, acid from organic sulfur is not accounted for, and erroneous results often occur. For this reason a substantial research effort exists in the eastern United States to develop a method that has good reproduceable accuracy. In addition, the Montana Abandoned Mines Program has funded a new research project at Montana State University where a sample weathering technique will be developed to determine the total lime requirement for acid mine sites.

ALTERNATIVES TO TOPSOIL AND LIMING APPLICATIONS

At abandoned mines in Montana, adequate volume of cost feasible topsoil may not be available for reclamation of acid waste material. Likewise, the cost of lime in conjunction with possible inaccurate lime recommendations may open the door for alternate approaches to reclamation.

Organic Matter Amendments

Numerous studies from the eastern United States have reported excellent success in reclaiming abandoned mine materials (gob, slag, spoils, cinder) with sewage sludge and plant debris. Sewage sludge has been considered to be a desireable soil amend-

ment to assist in the reclamation of drastically disturbed lands for some time (Sopper and Kerr, 1979). The sludge contains organic matter and nutrients that are often lacking in disturbed lands and, thus, can be used to improve the chemical and physical properties of the waste material, inactivate heavy metals, and make it more suitable for the establishment of vegetation. A land surface with good vegetative cover is less subject to erosion. Investigators have demonstrated that sewage sludge often in combination with limestone can amend pyritic soil material so that it will support a good grass cover as well as shrubs and trees (Kerr and Sopper 1981, Hill et al. 1982, Schneider et al. 1981).

In Kentucky, pH neutral loam spoils had significantly better grass legume production during a three year period when treated with bark and/or sewage sludge compared to 3 to 9 inches of topsoil (Alderdice et al. 1981). Incorporation was to the 5 inch depth. Amendments were .75 T/A pelletized leaves, bark, sewage sludge, and .5 T/A wood fiber. Joost et al. (1981) established good stands of tall fescue redtop, and reed canarygrass on very acid-sand coal refuse material (gob piles) at a coal mine in Illinois with sewage sludge and limestone incorporated to the 1 and 2 foot depths. Application rates were high as 360 T/A dried sludge and 72 T/A limestone. Parallel rows of trenches enabled deep incorporation.

Most of the above cited studies monitored trace metal levels in the minesoil and vegetation. In general, no excessive metal concentrations were measured in plant materials.

Staff in the Montana Abandoned Mines Program indicate the Great Falls sewage treatment plant will soon be producing sludge with a very high pH (>10). The potential exists that this material could serve a dual purpose as an amendment for acid mine waste. The high pH of the sludge would elevate the pH of the mine waste and the organic matter will enhance the water holding capacity and soil structure. Cost feasibility of applying sewage sludge from Great Falls on mine wastes at Sand Coulee should be investigated.

ACID DRAINAGE CONTROL AT SAND COULEE WITH SOIL AMENDMENTS

Several investigators have observed that pyrite oxidation is limited to the uppermost 3 feet of material (Erickson et al. 1982). Pyrite oxidation may only occur to the 25 to 60 cm depth if fine texture or a profile hardpan is present (Von Demfange and Warner 1975, Good et al. 1970). Therefore it has been suggested that if the upper few feet of the minesoil profile can be chemically neutralized then deep acid mine drainage problems as well as revegetation problems will be solved.

This hypothesis was tested by Geidel and Caruccio (1982) where a 150 acre mined land watershed received 50 T/A lime. The pH in a few seeps increased somewhat but the pH of the stream draining the watershed remained acid (2.8-3.2). It was concluded that application of limestone was not effective in reducing acidity of drainage from a mine waste area. Other investigators tested whether compacted zones in the minesoil landscape could lessen acid mine drainage (Aspen and Aharrah, 1982). They found the treatment to be ineffective and seriously restricted plant establishment efforts.

The above investigators made a poor assumption when they indicated the source of acid mine drainage was largely associated with the oxidized zone, meaning top few feet of the minesoil profile. Acid mine drainage is more closely associated with the weathered zone which easily penetrates several tens of feet and as much as 100 feet deep. Although air exchange with the atmosphere is not probable at these depths, the penetration of water to these depths is common. Dissolved oxygen in water can provide the necessary catalyse to complete acid producing reactions with sulfide minerals. Acid production under anerobic conditions in the presence of a flush of water has been documented in spoil materials.

Therefore it is not likely that the pH of mine discharge will be changed significantly in the Sand Coulee project area due to surficially applied lime.

Kleinman and Erickson (1981) have had considerable success in amending acid mine drainage with surface application of a chemical bacteria inhibitor. Inhibition of an iron-oxidizing bacterium, Thiobacillus ferrooxidans slows the rate of pyrite oxidation and thereby reduces acidity in mine drainage from surface coal mines and coal refuse piles. Long-term inhibition was accomplished at a low cost by controlled release of sodium lauryl sulfate (SLS), an anionic surfactant, from rubber pellets. Approximately 7 lbs/A/ft were applied.

If acid mine drainage is considered a serious problem at Sand Coulee a dump area and associated drainage site could be tested with SLS.

CINDER WASTE SALINITY

The cinder waste at the Sand Coulee site has a very high salt content. These materials generally had salt contents at the 30 mmhos/cm level as well as being very acid (Westech, 1983). Plant root development would be minimal in the acid medium and the high salt content would desiccate whatever roots were present. Liming the cinder waste will amend only the ph, not the high salt content.

The cinder material must be either leached with water or buried. Leaching with water is often a slow process and may not be feasible at this site due to steep slopes, water availability and costs. The reclamation engineering plan should consider the cost of burying saline cinder waste piles (note: a few are not saline) with 2 feet of acid waste material that is not saline. The acid waste can be amended with lime. Obviously two feet of topsoil would be best, but use of the acid waste is probably more feasible.

If a few inches of topsoil were placed directly on the saline cinder waste, it is probable that the topsoil would salinize in a short time due to upward salt migration.

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APPENDIX E

REVEGETATION METHODS

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REVEGETATION METHODS

INTRODUCTION

Information regarding the reclamation of abandoned minelands is scarce, particularly from the semiarid west. The best reclamation technology currently available which may be applicable to the reclamation of derelict mineland in Montana has been derived from demonstration studies conducted in the Belt/Sand Coulee areas, and from studies of surface coal mine reclamation in southeastern Montana (DePuit and Coenenberg 1979, DePuit and Coenenberg 1980, Coenenberg 1982). Other useful information regarding the treatment of acidic substrates may be derived from studies conducted in other geographic regions of the United States (Mays and Bengston 1978, Farmer et al. 1976, Dean and Shirts 1977).

This section will outline reclamation alternatives, types of sites which may require reclamation, and applicable reclamation methods. Cost estimates for various treatments are also provided.

A variety of methods can be utilized during the revegetation phase. They are discussed in some detail in the following section. It must be realized that any combination of methods may be suitable for revegetation of a given site. Thus, the following discussion will be of a general nature. Site specific revegetation methods will be presented during phase II of this study.

Amendments - Lime

The addition of amendments to coal slag or slag affected materials is important if they are to serve as substrates for plant growth. At Sand Coulee, many of the slag piles are acidic, high in soluble salts, or have high metal content. Any of these properties may render a substrate unsuitable for plants. Acidity (pH 2.5 to 4.0) is usually not a problem for plant growth (Mays and Bengston 1978). Acidic soils (pH 3.5) were supporting what appeared to be "normal" plant (Westech/Hydrometrics 1981). However, acidity is problematic as it decreases fertility and increases the mobility of heavy metals in the soil. Thus, remedial treatment (usually the addition of lime) is required in order to raise soil pH to acceptable levels (6.0 or higher).

Liming materials are either oxides, hydroxides or carbonates of lime (Brady 1974). Oxides and hydroxides react more quickly than carbonates, however they are also more expensive. Carbonates are either calcitic ($CaCO_3$) or dolomitic [$CaMg(CO_3)_2$]. Dolomite reacts more slowly than calcite, thus, the effective period of neutralization could be prolonged through the use of dolomite. Kiln dust, a by product of the concrete manufacturing process, may be substituted for lime. It has a high Calcium carbonate equivalence (176%), is readily available, and is considerably less expensive than lime ($2.00 per ton vs. up to $65.00 per ton for lime).

Since reacidification is a potential problem at Sand Coulee limestone and/or kiln dust are recommended for neutralization of acidity (oxides and hydroxides react quickly, thus, their effective period of neutralization is reduced). Perhaps the best approach to long term neutralization would be the application of a mixture of kiln dust and coarse dolomitic limestone. The fine kiln dust would provide immediate neutralization, while the coarse lime would react more slowly and thus, prolong the neutralization period. However, until further research is conducted on liming rates and strategies, it will be difficult to predict the duration and success of any liming treatment.

Dollhopf (1983) indicated that liming would not correct the high salt levels exhibited by some slag piles. Saline materials would require burial or leaching with water (in order to remove salts). Leaching may not be possible due to limited water availability and high cost. Also, limited soil data complicates the selective shipping and placement of saline slag materials. However, since some slag piles do support vegetation, it may be inferred that they are not as toxic to plants as piles which are devoid of vegetation. Hence, "barren" slag piles would be likely choices for pneumatic injection; or, should be the first materials to be buried. Toxic materials can then be covered with slag materials which appear to be less limiting for plant growth.

Lime can be applied by spinner type spreaders mounted on trucks (Mays and Bengstom 1978) and then incorporated into the soil/slag by disking or plowing.

Municipal Sewage Sludge

Municipal sewage sludge is a potential amendment for improving the physical and chemical properties of acidic slag materials. Halderson and Zenz (1978) indicated that sewage sludge additions may increase soil organic matter content, and can also supply nutrients to the soil. Typical N, P, K levels for municipal sludges are 5:2.5:0.4, respectively, on a % of dry matter basis (Halderson and Zenz 1978). However, sewage sludges are also sources of heavy metals. If reacidification problems are not yet fully understood, sewage sludge additions would likely intensify heavy metal levels in the soil; increasing acidities would also increase the solubility and mobility of heavy metals in the soil. Hence the ultimate land use will dictate the utility of sewage sludge applications and application rates. If sewage sludge is used to reclaim slag materials, plants which are known or suspected to concentrate heavy metals in their tissues should not be used for revegetation. Regardless, sewage sludge cannot be recommended as a slag amendment until studies have been conducted (under rangeland conditions).

Topsoil

Covering regraded slag surfaces with topsoil would increase the chances for successful vegetation establishment. In general, there is a correlation between agronomic production and topsoil depth (Power 1978) and between rangeland production and thickness of mollic epipedons (Munn et al. 1978). At the Armington pneumatic demonstration site, 4 to 6 inches of "topsoil" was placed over a former waste pile area; vegetation establishment appeared to be satisfactory (Westech/Hydrometrics 1981). However, adequate topsoil may not be available to topdress all of the potential Sand Coulee sites which may be reclaimed. Alternatives include using less top soil, and/or use of subsoil (B horizon material) in lieu of topsoil, or not topsoiling at all. While B horizon materials are not as suitable as A horizon ("topsoil"), they (B horizon) generally have physical (textural) and chemical properties which are superior to coal slag. Where topsoil is not used, slag materials would require extensive treatment (lime, fertilizer, etc.) in order to render them suitable as plant growth media.

Dollhopf (1983) indicated that there was no scientific evidence which showed that a few inches (4 inches) of topsoil would be adequate for reclamation at Sand Coulee. Although initial revegetation results appeared to be promising, he was concerned with gradual reacidification of much or all of the topsoil layer, thus resulting in long term revegetation failure. Dollhopf (1983) cited a study (Barth and Martin 1982) in which a topsoil "wedge" (0 to 5 feet thick) was constructed over acidic spoil materials (pH 3.6 to 4.3) at two coal mine sites in Wyoming. As soil depth increased, perennial grass yield increased in a linear manner and maximum yields occurred at topsoil depths greater than five feet (the maximum wedge depth). Root penetration into acid spoil was minimal and never exceeded eight inches. Plant roots always penetrated to the maximum depth of the topsoil provided.

Fertilization

Fertilizer application is recommended on deficient soils and/or slag material. The most commonly applied fertilizer elements are nitrogen (N), phosphorus (P), and potassium (K) (Brady 1974). In the Great Plains and Intermountain regions, additions of N and occassionally P have generally resulted in increased pasture production; K is usually adequate in most western rangeland soils. (Vallentine 1977).

Semiard sites (such as upland range sites at Sand Coulee) generally require less nitrogen than mesic sites. Thus, fertilizer application rates for upland sites would logically be lower than for riparian sites. Fertilizer rates for disturbed areas are often similar to those required for nearby agricultural soils (Nielson and Peterson 1978). Thus, where topsoil is to be used, fertilizer additions which satisfy nutrient deficiencies in these topsoils would likely be adequate (assuming soil acidity and salinity problems have been corrected). Normal fertilization rates for agricultural soils are 50 lbs/ac N, 30 lbs/ac P (dryland) and 120-150 lbs/ac N, 50 lbs/ac P, and 30 lbs/ac potash (irrigated).

Nitrogen fertilizer rates of 20 to 30 pounds per acre may be adequate for semiarid areas (Valentine 1977). DePuit and Coenenberg (1979) indicated that "light" (33 lbs/ac N) applications may be adequate on topsoiled surface coal mined sites in southeastern Montana. Wight (1974) indicated that single applications of N (90 lbs/ac or more) were more effective than equivalent amounts applied in two or three annual incrememants. Farmer et al. (1976) reported satisfactory stand establishment on acid mine wastes in Idaho which were fertilized with 435 lbs/ac of 18-46-0. At the Armington pneumatic demonstration site, application of 300 lbs/ac of 18-46-0 resulted in good initial stand development (Westech/Hydrometrics 1981). Thus, these latter rates may be adequate for fertilization of riparian zones (435 lbs/ac, 18-46-0) and for upland sites (300 lbs/ac 18-46-0).

Since the objective of reclamation is to establish stands of vegetation which are capable of self regeneration, heavy and/or repeated fertilization cannot be justified. Ideally, fertilizer additions should be based on fertility tests conducted on soils to be used for topsoiling. Also, continued monitoring of soil fertility levels and vegetation performance is recommended on an annual basis.

Mulch

Mulches are usually applied to soils during or following seeding. Mulch acts as a temporary soil surface stabilizer, may reduce evaporative moisture loss, and may also afford some degree of protection to seedlings. Straw and/or hay are most commonly used for mulch in the western United States (Kay 1978). However, a variety of other substances including netting, synthetic emulsions and hydromulches may be utilized. Generally these are more costly to apply, and thus, are reserved for use in extremely difficult reclamation situations.

Straw or hay mulches may be applied at rates of one to two tons per acre. They are usually applied by commercial mulch spreaders or straw blowers (Kay 1978). Mulch should be anchored in order to increase its effectiveness. Crimping, rolling or chemical tackifiers are most often used to hold straw mulches in places. Jute netting may have some utility as a temporary stabilizer, especially where small linear areas (such as topsoiled riparian areas) require stabilization. Hydromulches can be used on sites which are difficult to seed, fertilize, and/or mulch conventionally.

Seeding Methods

Seeding methodology will be determined by the size of the area to be seeded, its accessibility, slope steepness and seedbed characteristics. Large, gently sloping (3:1 slopes or less) accessible areas, with firm, smooth, rock free seedbeds can be drill seeded. Similar sites, with

slopes of 2:1 or less, and with "roughened" seedbed surfaces can be broadcast seeded. Drilling operations plant and cover seed in one step. However, with proper implements, broadcast areas may be seeded and covered in one operation as well. Equally successful results can usually be obtained by either method, especially when broadcast seed has been covered. Hence, harrowing is recommended on sites which have been broadcast seeded, "mechanical" seedings should be conducted along slope contours.

Sites which are too small and/or steep to accomodate seeding machinery are best broadcast manually. Cyclone broadcast seeders are best suited for these areas. Hand broadcast seed should also be covered. Hand raking, horse drawn harrows (or other implements) or hydromulches can be used to cover broadcast seed on small sites.

Other small or difficult sites (i.e. slopes 3:1 or greater; or upper banks of riparian zones) may be hydroseeded. Depending on the operation hydroseeding may combine seeding, fertilization and mulch application into one process (Kay 1977).

Seeding rates and depths

Broadcast seed rates are generally one and one half to twice that recommended for drilling; hence broadcast seed costs will be somewhat higher. However, where mixtures of different sized seed are used, broadcasting is superior to drilling in achieving overall stand diversity (DePuit and Coenenberg 1980). This is attributed to the fact that the various sized seeds are more apt to settle at proper germination depths (as opposed to drilling, which places all seed at a uniform depth). In general, seeding depth should be increased with seed size. Small seed should be planted one-quarter inch deep, medium sized seed at one-half inch, and large seed up to one inch deep (Wambolt 1976).

Scasonal

Fall [illegible] Great [illegible] Seeding during the [illegible] allows for overwinter seed stratification and may [illegible] germination. Thus, fall seed is already present to take advantage of spring moisture. Spring seeding may yield results comparable to [illegible] "mechanical seeding" [illegible] unfavorable [illegible]

Species Selection

The baseline upland range survey (Wetherhyd[illegible]) and the riparian [illegible] (Cook [illegible]) provided [illegible] regarding species which [illegible] Coulee. The riparian survey also provided [illegible] species which might be somewhat tolerant of acidic conditions.

Table [illegible] includes species which may [illegible] Sand Coulee. These species which have [illegible] tolerance have been referenced to some authority. Some is available for most of the herbaceous species listed [illegible] successfully established [illegible] these species should be [illegible] conditions. Where need for a particular [illegible] should be taken for subsequent growth [illegible] developed an adequate root system, and [illegible] can be transferred to the field for [illegible]

For maximum adaptability, [illegible] the intended planting sites [illegible] 500 km north, or [illegible] to 200 km [illegible] compare [illegible] soils and climate may [illegible] 1957, [illegible] Thornburg and Fuchs 1978 [illegible] movements may be similar, depending on changes in elevation and precipitation.

Season of Seeding

Fall dormant seedings are generally recommended in reseeding Northern Great Plains rangeland. Seeding during the fall allows for overwinter seed stratification and may thus increase germination. Also, fall sown seed is already present to take advantage of spring moisture. Spring seeding may yield results comparable to fall seeding. However, "mechanical" seeding during the spring may be delayed or prohibited due to unfavorable site conditions (i.e. soils too wet).

Species Selection

The baseline upland range surveys (Westech/Hydrometrics 1981) and the riparian vegetation surveys (ECON 1983) provided information regarding species which might be suitable for revegetation at Sand Coulee. The riparian surveys also provided insights as to species which might be somewhat tolerant of acidic conditions.

Table includes species which may be suitable for revegetation at Sand Coulee. Those species which have demonstrated some degree of acid tolerance have been referenced to some authority. Seed is available for most of the herbaceous species listed. Few woody species can be successfully established from seed under field conditions, hence, seed for these species should be collected, germinated and grown under greenhouse conditions. Where seed for a particular shrub is not available, cuttings should be taken for subsequent growth in a greenhouse. Once species have developed an adequate root system, and have attained sufficient size, they can be transferred to the field for planting.

For maximum adaptability, plant materials should originate as near the intended planting sites as possible. However, ecotypes moved 400 to 500 km. north, or 150 to 200 km south of the point of origin to areas of comparable soils and climate may still perform satisfactorily (Cooper 1957, in Thornburg and Fuchs 1978). East and west movements may be similar, depending on changes in elevation and precipitation.

Nursery Grown Shrub Stock

Nursery grown shrub stock plantings are recommended to aid in the establishment of woody vegetation, particularly in riparian areas. Shrubs should be planted in "clumps" as this would appear more natural and would also increase the chances for survival of any given "clump". Clumps of 15 to 20 individuals may suffice. Small shrubs, perhaps up to one foot in height are best planted by hand. Larger stock (up to 6 feet) may be planted with the use of a mechanical tree spade.

Ba[illegible] Martin. [illegible] Soil-[illegible] requirements to reclaim surface-[illegible] areas in the Northern Great Plains. Colorado School of [illegible] Colorado, [illegible]

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DePeit, [illegible] and [illegible] strip mine spoils to [illegible] fertilization [illegible] Reg. 158. [illegible]

D[illegible] and [illegible] plant [illegible] Reg. [illegible]

Do[illegible]

Fa[illegible] 1[illegible]-178. [illegible]

Hal[illegible]

[illegible]

Ka[illegible] 1977. [illegible] In: J. L. [illegible] Southwest. Univ. [illegible]

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[illegible]

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Table. Species [illegible] in association at Sand Co. [illegible]

[illegible]	[illegible]	Site [illegible]	Site [illegible]	Sand Co. [illegible] (Author(s))
[illegible]	[illegible]	[illegible]	√	
[illegible]	[illegible]	[illegible]	√	1,2
[illegible]	[illegible]	[illegible]	√	
[illegible]	[illegible]	[illegible]	√	
[illegible]	[illegible]	[illegible]		3,4
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	√	
[illegible]	[illegible]	[illegible]		2,[illegible]
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		5
[illegible]	[illegible]	[illegible]	√	[illegible]
[illegible]	[illegible]	[illegible]	√	2,3,[illegible]
[illegible]	[illegible]	[illegible]	√	3,4
[illegible]	[illegible]	[illegible]	√	1,2
[illegible]	[illegible]	[illegible]	√	
[illegible]	[illegible]	[illegible]	√	
[illegible]				
[illegible]	[illegible]	[illegible]		3
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	√	
[illegible]	[illegible]	[illegible]		4
[illegible]	[illegible]	[illegible]		
[illegible]				
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	√	2
[illegible]	[illegible]	[illegible]	√	2
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		2
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		4
[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		2

[illegible] 1 [illegible]
[illegible] [illegible]
[illegible] [illegible]
[illegible] [illegible] (1969).
[illegible] [illegible] 1 (1970).
[illegible] [illegible] (1969).
[illegible] [illegible] (1976).

Potential Species for Revegetation at Sand Coulee.

BINOMIAL	Common Name	Site: Upland	Site: Riparian	Acid tolerance (Authority)
GRASSES				
Agropyron cristatum	crested wheatgrass	✓	✓	
Agropyron repens	quackgrass		✓	1,2
Agropyron smithii	western wheatgrass		✓	
Agropyron spicatum/inerme	bluebunch wheatgrass	✓		
Alopecurus pratensis	meadow foxtail		✓	3,4
Bouteloua curtipendula	sideoats grama	✓		
Bouteloua gracilis	blue grama	✓		
Bromus inermis	smooth brome		✓	2,3
Dactylis glomerata	orchardgrass		✓	
Festuca arundinacia	tall fescue		✓	5
Festuca ovina	sheep fescue	✓		4
Oryzopsis hymenoides	Indian ricegrass	✓		2,3,4
Phleum pratense	timothy		✓	3,4
Poa pratensis	Kentucky bluegrass		✓	1,2
Stipa comata	needleandthread	✓		
Stipa viridula	green needlegrass		✓	
FORBS				
Achillea millefolium	western yarrow	✓		3
*Astragalus cicer**	cicer milkvetch	✓		
Linum perenne	blueflax	✓	✓	
*Medicago sativa**	alfalfa	✓	✓	4
Ratibida columnifera	prairie coneflower	✓		
SHRUBS				
*Atriplex canescens***	fourwing saltbush	✓		
*Ceratoides lanata***	winterfat	✓		
Fraxinus pennsylvanica	green ash		✓	2
Populus deltoides	plains cottonwood		✓	2
Populus trichocarpa	black cottonwood		✓	2
Prunus virginiana	chokecherry		✓	2
Rhus trilobata	skunkbush sumac	✓		
Ribes aureum	golden currant		✓	
Ribes setosum	redshoot gooseberry		✓	
Rosa arkansana/woodsii	rose		✓	2
Symphoricarpos albus/occidentialis	snowberry		✓	2

* Should be inoculated with *Rhizobium*.
** Can be established from seed.
1 Plummer (1977).
2 This study (1983).
3 Farmer et al (1976).
4 Sindelar et al (n.d.).
5 Nielson and Peterson (1978).